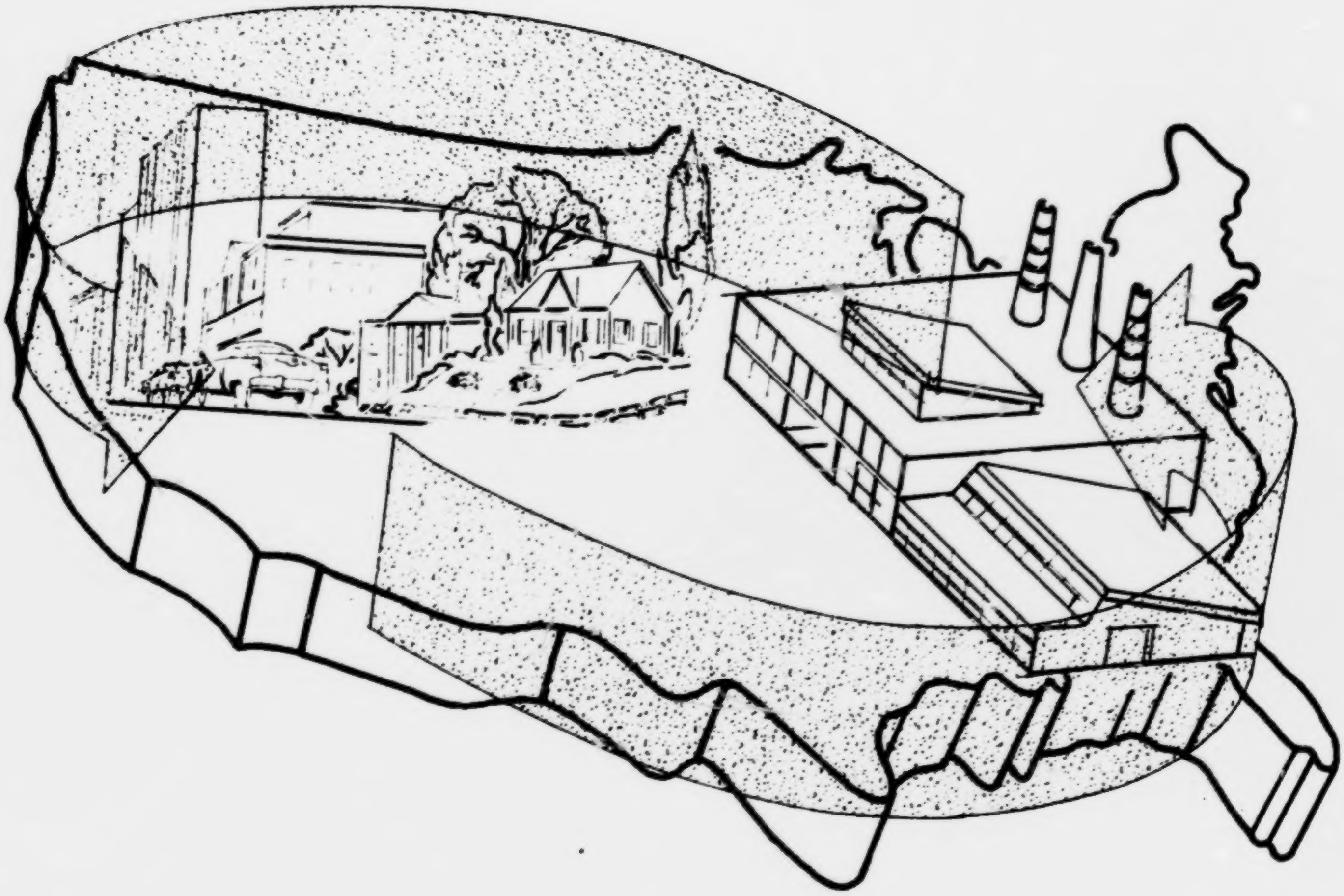
PB 199 181

MOUNT STORM, WEST VIRGINIA – GORMAN, MARYLAND, AND LUKE, MARYLAND – KEYSER, WEST VIRGINIA, AIR POLLUTION ABATEMENT ACTIVITY



U.S. ENVIRONMENTAL PROTECTION AGENCY

Reproduced by
NATIONAL TECHNICAL
INFORMATION SERVICE
Springfield, Va. 22151

BIBLIOGRAPHIC DATA SHEET

1. Report No. APTD-0656

2.

3. Recipient's Accession No.

4. Title and Subtitle
Mount Storm, West Virginia - Gorman, Maryland, and Luke, Maryland - Keyser, West Virginia, Air Pollution Abatement Activity

5. Report Date April 1971

6.

7. Author(s)

8. Performing Organization Rept. No.

9. Performing Organization Name and Address
U. S. Environmental Protection Agency
Air Pollution Control Office
Research Triangle Park, North Carolina 27709

10. Project/Task/Work Unit No.

11. Contract/Grant No.

12. Sponsoring Organization Name and Address
Same as above

13. Type of Report & Period Covered Technical

14.

15. Supplementary Notes

16. Abstracts

A report based upon an investigation of air pollution conducted the Mt. Storm, West Virginia, - Gorman, Maryland, and Luke, Maryland - Keyser, West Virginia, areas in 1969 and 1970, is presented. This report has been divided into two parts. Part One is concerned primarily with the Mt. Storm, West Virginia-Gorman, Maryland, area where air-pollution related damage to commercial tree growing operations has been cited as a major problem. Part two deals with air pollution problems in the Luke,Maryland - Keyser, West Virginia, area caused by particulates matter and noxious sulfur gases released from industrial plants in the area.

(APCO abstract)

17. Key Words and Document Analysis. 17a. Descriptors
Air pollution effects (plants)
Trees (plants)
Industrial wastes
aerosols
dusts
flue gases

17b. Identifiers/Open-Ended Terms
Mt. Storm, West Virginia
Gorman, Maryland
Luke, Maryland
Keyser, West Virginia

17c. COSATI Field/Group 13/B

18. Availability Statement
Unlimited

19. Security Class (This Report) UNCLASSIFIED

20. Security Class (This Page) UNCLASSIFIED

21. No. of Pages 158

22. Price

TECHNICAL REPORT

MOUNT STORM, WEST VIRGINIA – GORMAN, MARYLAND, AND LUKE, MARYLAND – KEYSER, WEST VIRGINIA, AIR POLLUTION ABATEMENT ACTIVITY

PRE-CONFERENCE INVESTIGATIONS

U.S. ENVIRONMENTAL PROTECTION AGENCY
Air Pollution Control Office
Research Triangle Park, North Carolina
April 1971

FOREWORD

This report is based upon an investigation of air pollution conducted in the Mt. Storm, West Virginia – Gorman, Maryland, and Luke, Maryland – Keyser, West Virginia, areas in 1969 and 1970. The report is intended to assist the governmental agencies concerned with such air pollution in their consideration of the following:

1. Occurrence of air pollution subject to abatement.
2. Adequacy of measures taken toward abatement of the pollution.
3. Nature of delays, if any, in abating the pollution.
4. Necessary remedial action, if any.

To simplify and clarify reporting reporting of information and data on the diversified air pollution problems in the interstate area, the report has been organized into two parts. Part One is concerned primarily with the Mt. Storm, West Virginia – Gorman, Maryland, area where air-pollution-related damage to commercial tree-growing operations has been cited as a major problem. Part Two deals with air pollution problems in the Luke, Maryland – Keyser, West Virginia, area caused by particulate matter and noxious sulfur gases released from industrial plants in the area.

LIST OF FIGURES

Page

1-1. Aerial Photograph of Mt. Storm Power Station Showing Existing Facility and Construction Underway for New Steam-Generating Unit 1-6

1-2. Mt. Storm, West Virginia - Gorman, Maryland, and Luke, Maryland - Keyser, West Virginia Abatement Activity Area 1-9

1-3. Geographical and Topographical Features of Study Area 1-12

1-4. Location of Study Area in Relation to Urban Areas in Eastern Maryland and Neighboring States. 1-13

1-5. Wind Rose of Surface and Upper-Level Winds at Elkins, West Virginia, for Period 1948 through 1952 1-15

1-6. Photograph of Premium-Quality Eastern White Pine Growing on Steyer Farm, 1964 1-24

1-7. Location of Tree Farms Surveyed for Damage 1-32

1-8. Aerial Photograph Showing Proximity of Stony River Farm (Foreground) to Mt. Storm Power Plant 1-33

1-9. Branch of Scotch Pine from Stony River Farm Showing Three Types of Abnormal Growth Symptoms: Early Needle Loss, Lateral Bud Failure, and Random Dwarfing of Needles 1-34

1-10. A. Damaged Spruce at Steyer Farm. B. Normal Spruce at Custer Home Farm 1-35

1-11. Stunted Growth of Scotch Pine Seedling Severely Burned by SO_2 in 1969 Compared with Nearly Normal-Sized Seedling of Same Age 1-37

1-12. A. Typical Severely Damaged Branches on Scotch Pine Recently transplanted from Stony River Farm to Custer Home Farm 1-39
  B. Healthy Current Growth on Trees Transplanted in 1969 That Recovered from Previous Damage 1-39

1-13. Abnormal Growth on Branches from Formerly Healthy Scotch Pine Transplanted to Stony River Farm 1-40

1-14. Laboratory-Induced Dwarfing of Needles 1-42

1-15. Cross Section of Pine Leaf 1-43

1-16. Location of Potential Air Pollution Sources in Study Area 1-49

1-17. Location of Static Sampling Stations 1-56

1-18. Location of Continuous Air Monitoring and Wind Observation Stations 1-57

1-19. Continuous Recording of SO_2 Concentration for 0800 to 1800 Hours on September 12, 1970 1-58

1-20. Distribution of Sulfation Rates. 1-60

1-21. Diurnal Variation of Ozone on August 26, 1970 1-62

1-22. Mean Diurnal Variation of Ozone/Oxidant for August 26 to September 9, 1970 1-63

1-23. Distribution of Dustfall Rates 1-65

1-24. Distribution of Fluoridation Rates 1-67

2-1. Aerial View Looking West Over Westernport; Denuded Ridge to Left Bears Brunt of Emissions. Plume Rising to Left Center Locates the Luke Mill. 2-4

2-2. Topography of Luke - Keyser Area 2-6

2-3. View of Luke Mill Showing Electrostatic Precipitators to Left of Stack 2-12

2-4. Flow Chart of Sulfur Dioxide Control Program at Westvaco Mill in Luke, Maryland 2-17

2-5. Spatial Distribution of Sulfur Dioxide as Indicated by Sulfation Plate Data 2-27

LIST OF TABLES

Page

1-1. Winds at 1000 feet above Pittsburgh Airport for Period June through September Compared for 5-year Base Period and 1970........... 1-17

1-2. Percent Frequency of Inversion with Bases $\leq$ 500 feet, Pittsburgh, Pennsylvania, June 1955 through May 1959...................... 1-18

1-3. Persistence and Frequency of Episodes of Mixing Height $\leq$ 2500 feet and Wind Speed $\leq$ 13.5 mph, Pittsburgh, Pennsylvania, 1960 through 1964 (NCC Tabulations)................................ 1-18

1-4. Summary of Damage on Tree Farms.. 1-28

1-5. Total Sulfur Accumulation in Scotch Pine Needles from Selected Sites.. 1-45

1-6. Estimated Source Emissions... 1-54

1-7. Summary of Hourly Sulfur Dioxide Measurements, May 28 through September 28, 1970... 1-56

1-8. Summary of Hourly Nitrogen Oxides Measurements, May 28 through September 27, 1970... 1-60

1-9. Summary of Hourly Oxidant Measurements, May 29 through September 28, 1970.. 1-61

1-10. Cumulative Percent Frequency of Occurrence of Daily Average Total Fluoride, May 28 through September 28, 1970......................... 1-64

1-11. Cumulative Percent Frequency of Occurrence of Daily Average Suspended Particulates, June 13 through September 28, 1970........... 1-66

1-12. Major SO_2 Sources, Their Locations Relative to Three Air Monitoring Sites, and Percent Contributions to Total SO_2 Received by Each Site During an Average Growing Season.............................. 1-71

1-13. Peak 1-hour Average SO_2 Concentrations $\geq$ 0.05 ppm Grouped by Prevailing Wind Direction.. 1-74

A-1. Location of Static Sampling Stations................................... 1-84

A-2. Sulfation Network Results.. 1-86

A-3. Settleable Particulate Network... 1-88

A-4. Daily Suspended Particulate Concentrations............................ 1-89

A-5. Daily Total Fluoride Concentrations, June 13 through September 28, 1970.. 1-90

A-6. Fluoridation Network Results... 1-91

B-1. Mt. Storm Power Plant Equipment Data................................... 1-94

B-2. Monthly Power Generation from Coal and Coal Consumption for Mt. Storm Power Plant.. 1-95

B-3. Mt. Storm Power Plant Coal Information for 1970........................ 1-95

C-1. Wind Direction and Speed at Three Locations and Corresponding SO_2 Concentrations Recorded at Stony River Farm Air Monitoring Site, September 12, 1970..........

D-1. Comparison of Frequency of Wind Directions at Indicated Stations, ... 1-99
June through September 1970..........

2-1. Population of Luke — Keyser Region.......... 1-104

2-2. Precipitation and Temperature in Westernport, 1968.......... 2-7

2-3. Principal Malodorous Gases from Kraft Process.......... 2-7

2-4. Plant Emissions, 1970.......... 2-10

2-5. Particulate Emissions.......... 2-14

2-6. Sulfur Dioxide Emissions.......... 2-15

2-7. Total Reduced-Sulfur Emissions.......... 2-16

2-8. Suspended Particulates.......... 2-19

2-9. Dustfall, 1969.......... 2-23

2-10. Silver Tarnishing Rates, 1968.......... 2-24

2-11. Average Sulfation Rates, 1968.......... 2-24

2-12. Average Sulfation Rates, 1970.......... 2-25

2-13. Effects Comparison, 1968.......... 2-26

2-30

BLANK PAGE

CONTENTS

Page

PART ONE

MT. STORM, WEST VIRGINIA — GORMAN, MARYLAND, INTERSTATE AIR POLLUTION ABATEMENT ACTIVITY AREA

I. SUMMARY AND CONCLUSIONS.. 1-1
II. INTRODUCTION.. 1-5
    HISTORY OF PROBLEM.. 1-5
    FEDERAL ABATEMENT ACTIVITY.. 1-6
III. DESCRIPTION OF AREA.. 1-11
    GEOGRAPHY.. 1-11
    CLIMATOLOGY.. 1-14
    AIR POLLUTION METEOROLOGY.. 1-16
IV. ASSESSMENT OF TREE DAMAGE.. 1-21
    AIR POLLUTION-RELATED TREE INJURY.. 1-21
        Studies of Conifer Damage.. 1-21
        Conifer Injury Symptoms.. 1-22
    CHRISTMAS-TREE FARMS.. 1-23
        Injury Classification.. 1-25
        Damage Survey.. 1-27
        Transplantation Experiment.. 1-38
        Entomological Studies.. 1-40
        Histological Studies.. 1-42
        Chemical Studies.. 1-44
        Vegetation Experiments.. 1-45
        Impact of Tree Damage.. 1-46
    REFORESTATION AREAS.. 1-47
V. DESCRIPTION OF SOURCES.. 1-49
    MT. STORM POWER PLANT.. 1-50
    WESTVACO PULP MILL.. 1-51
    OTHER SOURCES IN STUDY AREA.. 1-51
        Burning Coal Refuse Banks.. 1-51
        Kingford Charcoal Plant.. 1-52
    SOURCES OUTSIDE STUDY AREA.. 1-52
        Albright Power Plant.. 1-52
        Manganese Corporation Plant.. 1-53

Other Coal-Fired Power Plants Outside Study Area 1-53
VI. AIR QUALITY MEASUREMENTS 1-55
SULFUR DIOXIDE 1-55
Continuous Measurements 1-55
Static Sulfation Measurements 1-58
NITROGEN OXIDES 1-59
OXIDANTS 1-61
PARTICULATE MATTER 1-63
Suspended Particulate Matter Measurements 1-63
Settleable Particulate Measurements 1-64
FLUORIDES 1-65
Total Fluoride Measurements 1-65
Static Fluoride Measurements 1-66
VII. ANALYSIS OF POLLUTANT DISTRIBUTION AND IMPACT 1-69
LONG-TERM DISTRIBUTION OF SULFUR DIOXIDE 1-70
Application of Diffusion Model 1-70
Potomac River Valley Airflow Study 1-72
SHORT-TERM DISTRIBUTION OF SULFUR DIOXIDE 1-72
Impact and Analysis 1-72
Acute Injury to Pine Trees 1-72
Aerial Measurement of Sulfur Dioxide 1-73
Correlation of Peak Sulfur Dioxide Concentrations and Wind Direction 1-73
LAPPES Analogy 1-75
FLY-ASH PROBLEM NEAR MT. STORM POWER STATION 1-76
VIII. REFERENCES 1-79
APPENDICES
A. AIR QUALITY DATA 1-83
B. MT. STORM POWER STATION DATA 1-93
C. SPECIAL METEOROLOGICAL STUDIES 1-97
D. METEOROLOGICAL DATA 1-103

PART TWO

LUKE, MARYLAND — KEYSER, WEST VIRGINIA, INTERSTATE AIR POLLUTION ABATEMENT ACTIVITY AREA

I. SUMMARY AND CONCLUSIONS 2-1
II. INTRODUCTION 2-3
HISTORY OF ABATEMENT ACTIVITY 2-3
DESCRIPTION OF AIR POLLUTION PROBLEM 2-3

III. AREA DESCRIPTION.. 2-5
IV. WESTVACO PULP AND PAPER MILL.. 2-9
    PLANT OPERATIONS... 2-9
        Pulp-Making Processes.. 2-9
        Power Boilers.. 2-13
        Summary.. 2-14
    CONTROL PROGRAM AND COMPLIANCE SCHEDULE.................................... 2-14
        Control of Particulate Emissions....................................... 2-15
        Control of Sulfur Oxides Emissions..................................... 2-16
        Control of Total Reduced-Sulfur Emissions.............................. 2-18
V. OTHER EMISSION SOURCES.. 2-21
VI. AIR QUALITY.. 2-23
    SUSPENDED PARTICULATE.. 2-23
    DUSTFALL... 2-23
    HYDROGEN SULFIDE... 2-24
    SULFUR DIOXIDE... 2-25
        Continuous Monitoring Equipment.. 2-25
        Sulfation Plates... 2-[illegible]
VII. EFFECTS... 2-29
    VISIBILITY REDUCTION... 2-29
    MATERIAL DAMAGE.. 2-29
    VEGETATION DAMAGE.. 2-30
    EFFECTS ON MAN... 2-30
VIII. REFERENCES... 2-31
    APPENDIX. WESTVACO COMPLIANCE PLAN... 2-33

PART ONE

MOUNT STORM, WEST VIRGINIA – GORMAN, MARYLAND, INTERSTATE AIR POLLUTION ABATEMENT ACTIVITY AREA

I. SUMMARY AND CONCLUSIONS

Commercial Christmas-tree farms in the mountainous rural area of Maryland and West Virginia bordering the North Branch of the Potomac River have suffered extensive damage in recent years. The poor quality of the trees was first noticed in early 1968 and became of increasing concern to the growers as the trees continued to decline in 1969 and 1970. Observations made by the U.S. Environmental Protection Agency's Air Pollution Control Office (APCO) confirm that the quality of trees on many of the farms has been seriously impaired. Affected trees have poor color, lack foliage, and frequently are disfigured to the extent that they are unsalable as Christmas trees. The existence of the large coal-fired power plant owned by Virginia Electric Power Company (VEPCO), which began operation in 1966 in close proximity to the tree farms, combined with injuries symptomatic of air pollution damage, suggests a cause-and-effect relationship.

Some of the tree injuries, such as discoloration and browning of needles, were found to be typical of SO_2 damage. Histological evaluation of needles exhibiting tip burn confirms that the causative agent is of a chemical nature, which clearly precludes the possibility that the damage results from insect or fungus infestation, winter damage, or wind exposure.

Abnormal growth symptoms such as random short needles, bud failure, and stunted growth were also noted. These symptoms are not typical of previously reported air pollution damage. Infestation by a relatively unknown species of eriophyid mite has been suggested as a cause of injury. Although the etiology of the damage is not fully understood, macroscopic and microscopic examinations of the injured needles and tissues indicate that inanimate causes such as acid burn are more likely to have been responsible. Laboratory tests presently are being conducted to confirm the existence of air-pollution-induced growth alterations.

VEPCO's 1160-megawatt Mt. Storm Power Plant south of Mt. Storm, West Virginia, is the largest source of particulate matter and sulfur oxides in the area. Located on a well-exposed site, it has the potential to affect air quality throughout the area. Expansion of the plant, which is currently underway, will significantly increase emissions and, accordingly, will increase the area affected and the potential for tree damage. The Mt. Storm plant is primarily responsible for the long-term SO_2 levels in an area within a 12-mile radius of the plant (which does not include that portion of the area beyond Backbone Mountain). The area includes all the tree farms where serious damage has been found.

The pollutant emissions from a large, isolated source such as the Mt. Storm plant would be expected to result in measurable SO_2 concentrations throughout the area. Long-term average concentrations will tend to decrease with increasing distance from the source. A source of this size could also produce very high short-term SO_2 levels whenever a relatively undispersed plume is brought to the ground through mechanical or thermal turbulence. Within the topographical boundaries of the area, the potential for acute exposure during inversion breakup or other atmospheric phenomena would not necessarily decrease with distance from the source. Although on most growing-season days some part of the area will be subjected to these high short-term concentrations, the incidence at any particular location will be infrequent. This limits the probability that representative measurements of short-term peak concentrations can be obtained at fixed sampling sites.

During APCO's LAPPES study of SO_2 concentrations associated with power-generating plants similar to the Mt. Storm plant, high ground-level concentrations, detected by mobile samplers, were found more than 20 miles from the plants. A similar episode was identified once during a 4-month period in 1970 at a sampling site on a tree farm close to the Mt. Storm Power Plant.

Even though the annual frequency of these acute exposures is low, the potential for serious damage exists during the 8-year period normally required to grow Christmas trees.

During 1969, severe burns—characteristic of acute SO_2 exposure—appeared on a number of tree farms, particularly those farms located southeast of Backbone Mountain in the vicinity of the Mt. Storm plant. Subsequent data evaluation showed that meteorological conditions favorable for the occurrence at the farm sites of acute ground-level concentrations of emissions from the Mt. Storm Power Plant were present during the period in which the damage occurred.

Eastern White Pine, noted for its susceptibility to air pollution, has exhibited damage area-wide, indicating that injury may be caused by low-concentration chronic exposure or by more than one pollutant or pollutant source. This finding is verified by the geographical distribution of sulfation rates measured in 1970, which indicates that power plants located outside and to the northwest of the study area are capable of influencing long-term SO_2 levels in the vicinity of some of the tree farms, particularly in the northern part of the area. Atmospheric diffusion calculations suggest that long-term SO_2 levels on the northwest side of Backbone Mountain are contributed to as much by these outside power plants as by the Mt. Storm Power Plant.

Air quality measurements obtained at three sites during the 1970 growing season showed sulfur dioxide concentrations below the proposed national air quality standards associated with vegetation damage. The almost complete absence of tip burn in 1970 on farms that showed severe burn in 1969 was commensurate with the generally low SO_2 values present in 1970. On the other hand, oxidant concentrations in the area reached levels considerably in excess of published criteria regarding damage to sensitive plants. Levels of oxidants also exceeded by a considerable margin the proposed national air quality standards. The source of the oxidants could not be determined on the basis of the available data. The presence of oxidants, because of possible synergistic effects, may magnify the potential for tree injury resulting from exposure to SO_2.

In conclusion, extensive damage to conifers has occurred in the study area. The damage is generally similar to air pollution damage; however, there are symptoms that have not as yet been linked to air pollution. Although measured air contaminant levels are below the proposed national air quality standards, the probability exists that short-term episodes sufficient to cause extensive damage will occur.

The large VEPCO plant has been identified as the main pollutant source. The emissions from this plant are capable of producing long-term pollution and exceptionally high short-term pollution concentrations throughout the area. Power plants outside the study area also were found to contribute to background or long-term pollution.

Until air pollution in the area is reduced, the quality of the trees will probably continue to decline. Because of the widespread air pollution damage evidenced on susceptible varieties of pine, serious doubts have been raised concerning the production of quality trees of these varieties anywhere in the area in the future. The prospect that trees on farms in the VEPCO vicinity can grow to maturity without being subjected to damaging concentrations of pollutants from the VEPCO plant appears doubtful unless the emissions from this plant are reduced.

II. INTRODUCTION

HISTORY OF THE PROBLEM

In the mid-1950's, commercial Christmas tree farms were started around the headwaters of the Potomac River in western Maryland. Christmas tree production in the area has had strong and steady growth since that time. More than 30 tree farms now exist in Garrett County, Maryland, with over a million trees being grown for future Christmas harvests and ornamental purposes. Until recent years, the tree growers were producing trees having the good color, shape, density, and needle-holding ability—qualities preferred by tree buyers—with no insurmountable problems. Some of the farmers developed reputations as producers not only of high-quality Christmas trees, but also of conifer seedlings and nursery stock.

In 1967, poor-quality trees began to appear in the field; and, as the spring and summer of 1968 passed, it became apparent to the Christmas tree growers that they were being confronted with a major problem. The trees were showing poor color, abnormal growth, premature needle drop, and a variety of other strange symptoms that appeared to grow progressively worse with each growing season. In searching for the cause of decline in quality of their trees, the growers learned that some of the symptoms were characteristic of air-pollution-related injury. They associated these symptoms, both in time and proximity, with the start-up of the Mt. Storm Power Station on the New Stony River Reservoir in West Virginia. The plant, owned by the Virginia Electric and Power Co. (VEPCO), is shown in the aerial photograph in Figure 1-1.

After a field investigation, VEPCO officials assured the growers that the Mt. Storm Power Station was not responsible for their troubles.[1] The growers then sought expert opinion from several sources—the U.S. Forest Service, the West Virginia Department of Agriculture, the Universities of Maryland and West Virginia, and the National Air Pollution Control Administration (now the Air Pollution Control Office). Not surprisingly, a variety of opinions resulted, ranging from winter injury and poor choice of tree stock to sulfur dioxide fumigation. The growers were understandably confused and widened their search for the cause of the continuing deterioration of their trees. Attention generated by newspaper stories of their plight in August 1969 resulted in widespread interest in the problem. Many experts in plant pathology, horticulture, entomology, and air pollution visited the farms during late summer and fall of 1969. While there were various points of view as to what kinds of injury were being experienced and what the causes of these injuries

PRECEDING PAGE BLANK

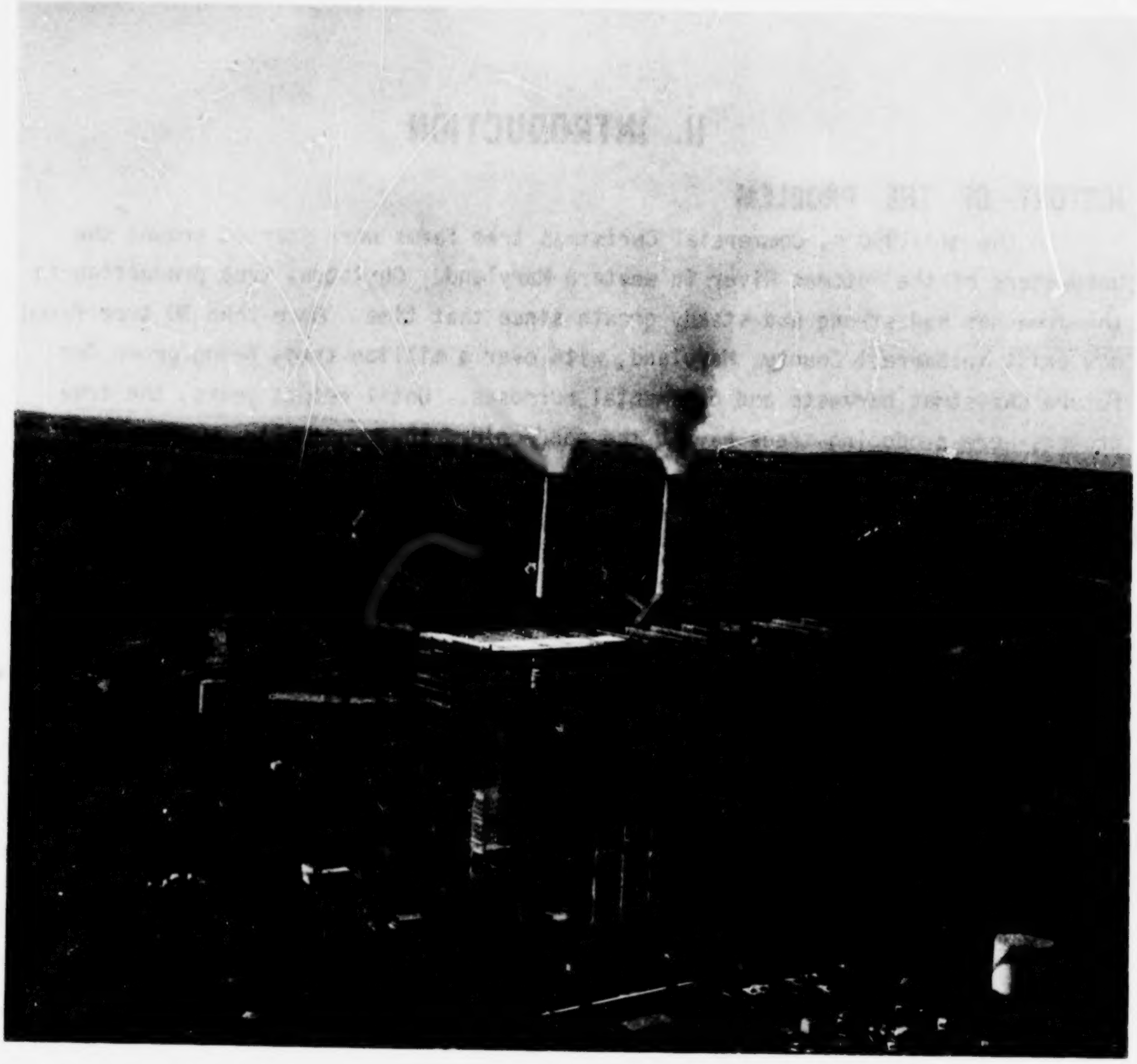


Figure 1-1. Aerial photograph of Mt. Storm Power Station showing existing facility and construction underway for new steam-generating unit.

might be, nearly all of the experts agreed that air pollution was causing at least some of the damage. Other kinds of growth aberrations not usually associated with air pollution were also exhibited by the trees.

FEDERAL ABATEMENT ACTIVITY

Senators Joseph D. Tydings and Charles McC. Mathias, Jr., and Representative J. Glenn Beall, of Maryland, were cognizant of the damage to the Christmas tree farms in the western part of their state and actively encouraged various government agencies working in related fields to investigate the problem. Senator Tydings, in a letter dated August 20, 1969, to the Secretary, U.S. Department of Health, Education, and Welfare, urged that a Federal survey be made to confirm officially the existence of interstate pollution, and that appropriate enforcement action be taken after review of the relevant data.

The conditions were found to warrant an investigation by specialists from the National Air Pollution Control Administration (NAPCA). A brief survey of tree damage and air quality of the area in November 1969, however, served to confirm the complexity of the problem and to establish the need for more data.

Extensive investigations of the meteorology, vegetation damage, and concentration of air pollutants in the area were performed during the 1970 growing season. The principal objectives of these studies were:

1. An assessment of the type and extent of damage on the affected tree farms.
2. Observations of the entomological conditions prevailing on the tree farms during the growing season.
3. Observations of the change in growth habits of trees that had been transplanted, grafted, or grown in filtered air of plant chambers.
4. A determination of air quality by means of static and continuous monitors and measurement of wind direction and speed.
5. A study of the symptoms of conifer injury, both chemically and histologically, to determine their cause.

In the formulation of the study, it was recognized that certain aspects of the project would of necessity continue for more than one growing season before definitive conclusions could be obtained. Because of this and the complexity of such tests, all the data from these various experiments have not yet been analyzed completely.

Since many of the symptoms exhibited by the affected trees were characteristic of sulfur dioxide fumigations, and since damage was seemingly greater at locations nearer the Mt. Storm Power Station, it seemed logical to conclude that the station caused at least part of the damage. Accordingly, on October 21, 1970, Governor Marvin Mandel of Maryland requested the Secretary, U.S. DHEW, to call an abatement conference in Garrett County, Maryland, regarding air pollution originating in West Virginia and allegedly affecting the health or welfare of persons in Maryland.

On November 19, 1970, NAPCA representatives met with officials of the West Virginia Air Pollution Control Commission and Maryland Department of Health and Mental Hygiene concerning an abatement conference. On January 8, 1971, Acting Commissioner John T. Middleton, of the Air Pollution Control Office of the newly formed Environmental Protection Agency, announced that a conference of air pollution control agencies would be held to consider interstate air pollution in the Mt. Storm, West Virginia - Gorman, Maryland, and the Luke, Maryland - Keyser, West Virginia, areas. The latter area, having a significant but more localized air pollution problem, is discussed in Part Two of this report.

The geographic area of the abatement action is defined as those counties, or portions thereof, encompassed by the following districts:

State of Maryland

Red House, Kitzmiller, Mountain Lake, Deer Park, Swanton, East Oakland, Sang Run, Westernport, McCoole, and Bloomington election districts in Garrett and Allegany Counties.

State of West Virginia

Union, Elk, New Creek, and Piedmont magisterial districts in Grant and Mineral Counties.

These districts are identified in Figure 1-2.

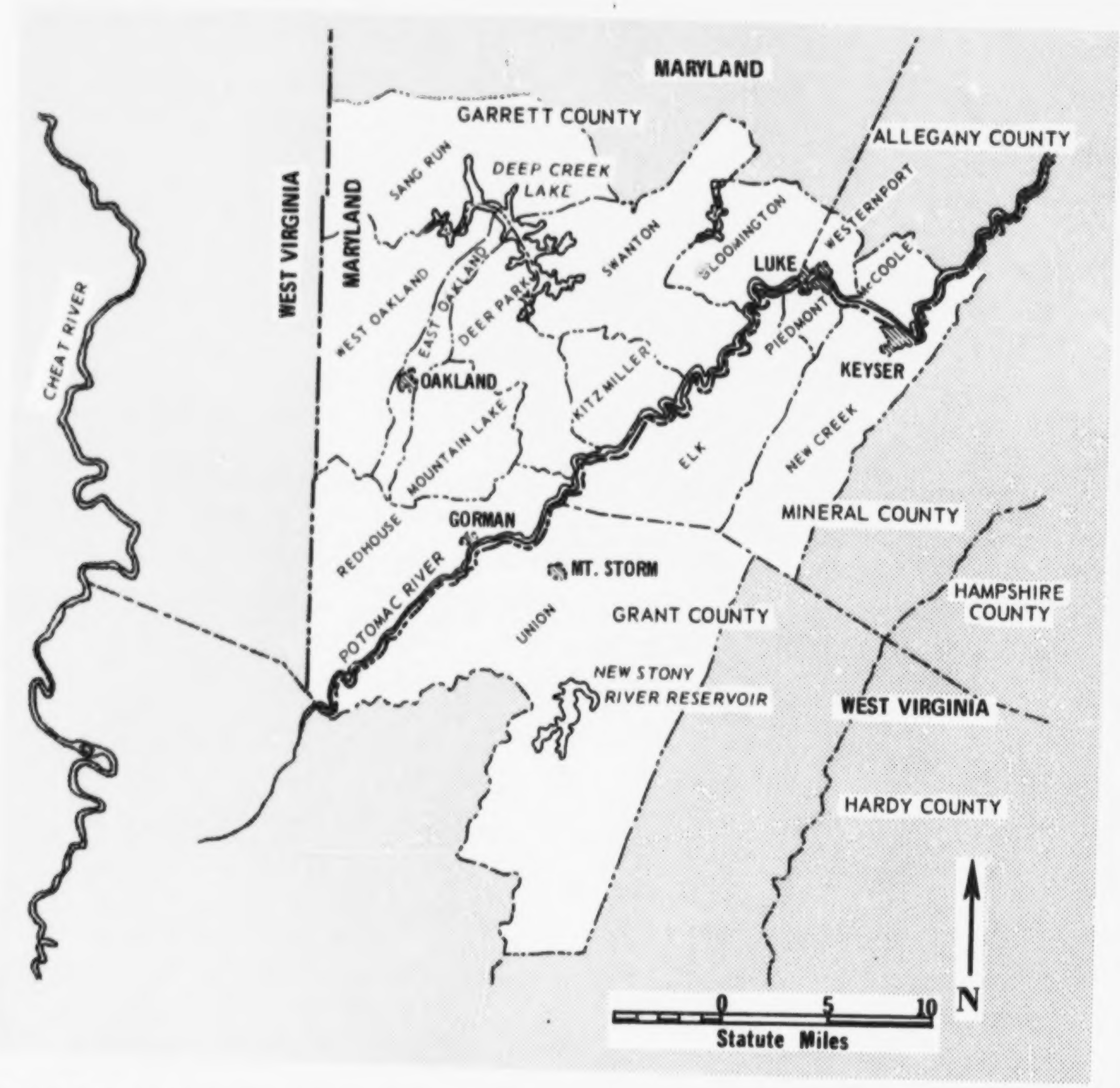

MARYLAND
GARRETT COUNTY
ALLEGANY COUNTY
WEST VIRGINIA
MARYLAND
SANG RUN
DEEP CREEK LAKE
SWANTON
BLOOMINGTON
WESTERNPORT
LUKE
McCOOLE
PIEDMONT
KEYSER
WEST OAKLAND
EAST OAKLAND
DEER PARK
OAKLAND
KITZMILLER
MOUNTAIN LAKE
ELK
NEW CREEK
CHEAT RIVER
MINERAL COUNTY
REDHOUSE
GORMAN
MT. STORM
POTOMAC RIVER
UNION
GRANT COUNTY
HAMPSHIRE COUNTY
NEW STONY RIVER RESERVOIR
WEST VIRGINIA
HARDY COUNTY
N
0
5
10
Statute Miles

Figure 1-2. Mt. Storm, West Virginia – Gorman, Maryland, and Luke, Maryland – Keyser, West Virginia, abatement activity area.

III. DESCRIPTION OF AREA

GEOGRAPHY

Garrett and Allegany Counties in western Maryland, and Grant and Mineral Counties of eastern West Virginia are part of a rugged mountainous region in the Allegheny Mountain Range of the Appalachians.

The Mt. Storm - Gorman portion of the abatement area centers on a high, rough, triangular-shaped plateau bounded by the Allegheny Front along its southeastern rim and by Backbone Mountain on the northwest. To the southwest, Cabin Mountain, with peaks more than 4,000 feet above mean sea level (MSL), forms a boundary. The average elevation of the area is above 2,600 feet, with the lowest point being about 1,000 feet near Bloomington, Maryland. The Allegheny Front towers almost 1,000 feet above any of the ridges to the southeast, whereas to the northwest of Backbone Mountain the ridges become progressively lower until relatively few peaks reach 2,000 feet MSL in the region of Morgantown, West Virginia.

The North Branch of the Potomac River flows northeastward through the western portion of the region, falling 2,500 feet in a twisting, scenic gorge over a distance of 25 miles to Luke, Maryland. The river forms the boundary between Maryland and West Virginia. Natural features of the area, referred to in later sections, are shown in Figure 1-3.

Sparsely settled and remotely situated from any major urban areas, as shown in Figure 1-4, the region is essentially rural and nonindustrialized. There are no major population centers, and the region's largest towns are well scattered through the two counties.

Garrett County, Maryland, had a population of 21,476 in 1970, and a land area of 659 square miles. Oakland, population 2,300, is the county's largest town and the center of population and trade. Grant County, West Virginia, had a population of 8,607 in 1970 and a land area of 478 square miles. The communities of Mt. Storm and Scherr are located in this county.

Both counties are mountainous and largely forested; some of the forests are state owned and some privately owned. Garrett County ranks first in Maryland in the sale of forest products.

PRECEDING PAGE BLANK

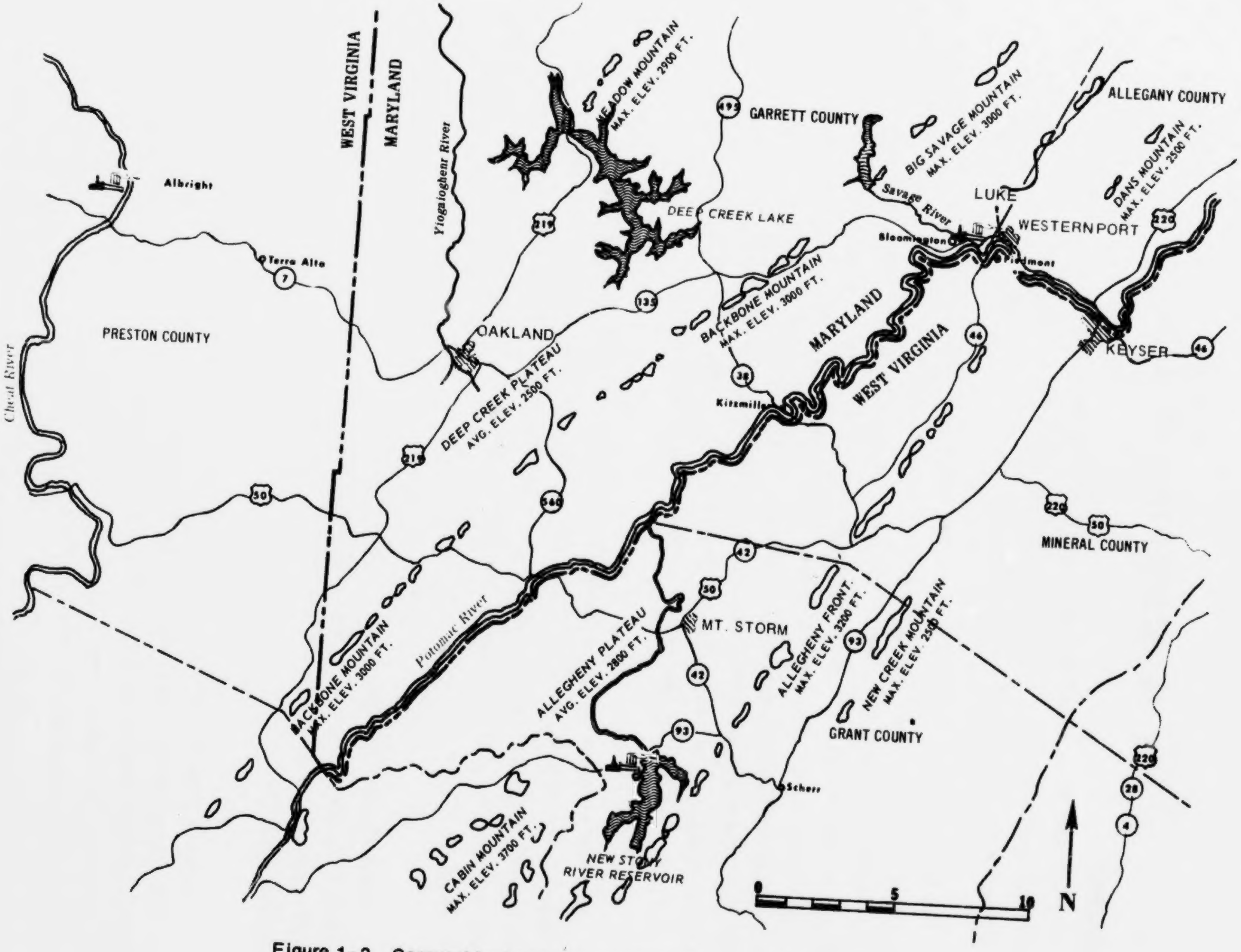

WEST VIRGINIA
MARYLAND
Albright
Terra Alta
7
PRESTON COUNTY
Cheat River
50
Youghiogheny River
219
OAKLAND
MEADOW MOUNTAIN
MAX. ELEV. 2900 FT.
DEEP CREEK LAKE
495
GARRETT COUNTY
BIG SAVAGE MOUNTAIN
MAX. ELEV. 3000 FT.
ALLEGANY COUNTY
DANS MOUNTAIN
MAX. ELEV. 2500 FT.
Savage River
LUKE
WESTERNPORT
Bloomington
Piedmont
220
135
BACKBONE MOUNTAIN
MAX. ELEV. 3000 FT.
MARYLAND
WEST VIRGINIA
46
KEYSER
38
Kitzmiller
DEEP CREEK PLATEAU
AVG. ELEV. 2500 FT.
560
220
50
MINERAL COUNTY
42
50
MT. STORM
ALLEGHENY FRONT
MAX. ELEV. 3200 FT.
93
NEW CREEK MOUNTAIN
MAX. ELEV. 2500 FT.
Potomac River
BACKBONE MOUNTAIN
MAX. ELEV. 3000 FT.
ALLEGHENY PLATEAU
AVG. ELEV. 2800 FT.
42
93
GRANT COUNTY
Scherr
220
28
4
CABIN MOUNTAIN
MAX. ELEV. 3700 FT.
NEW STONY
RIVER RESERVOIR
0
5
10
N

Figure 1-3. Geographical and topographical features of study area.

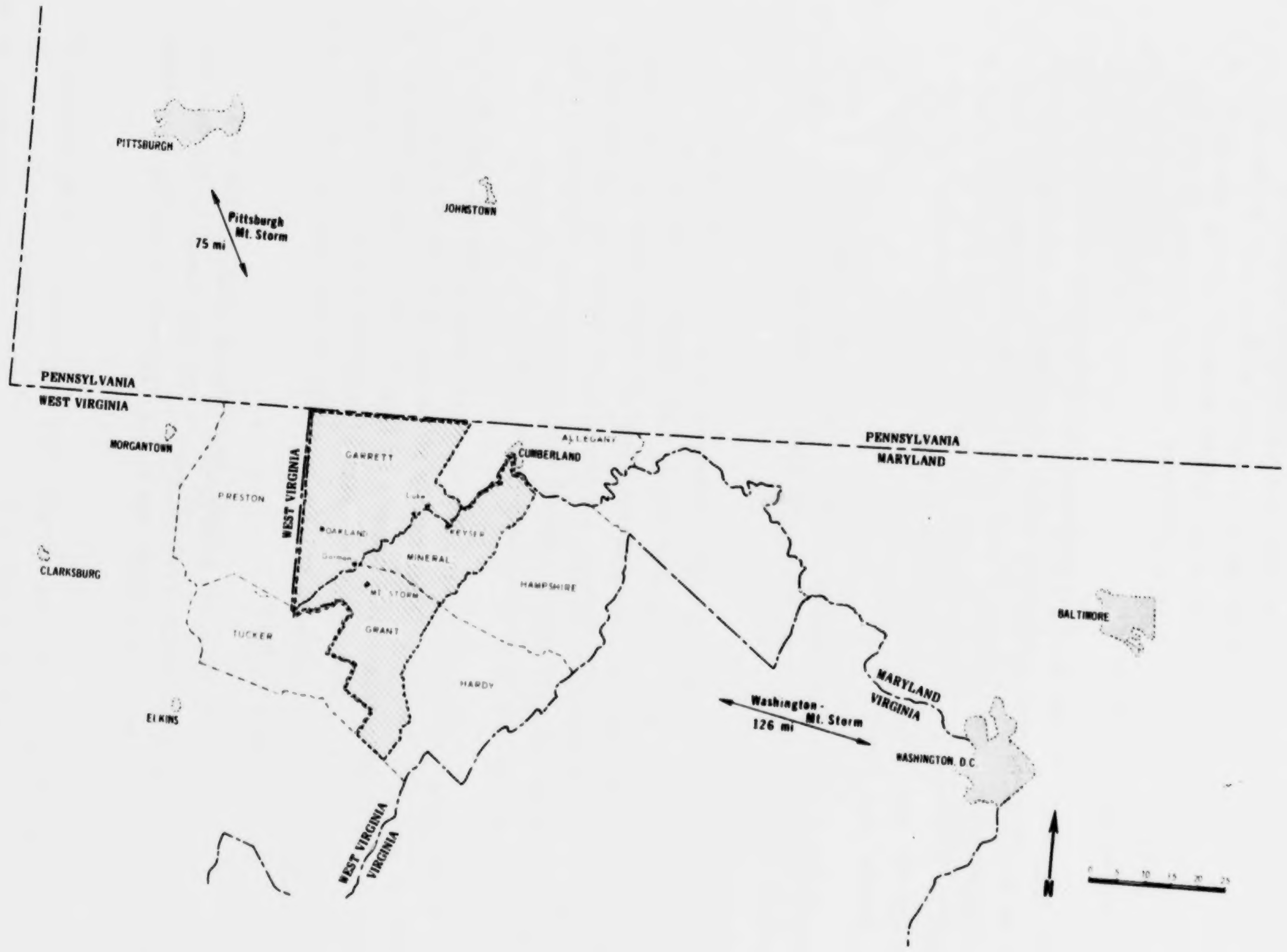

PITTSBURGH
Pittsburgh - Mt. Storm
75 mi
JOHNSTOWN
PENNSYLVANIA
WEST VIRGINIA
MORGANTOWN
CLARKSBURG
PRESTON
TUCKER
ELKINS
WEST VIRGINIA
GARRETT
Luke
OAKLAND
Gorman
MT. STORM
GRANT
MINERAL
KEYSER
CUMBERLAND
ALLEGANY
HAMPSHIRE
HARDY
PENNSYLVANIA
MARYLAND
WEST VIRGINIA
VIRGINIA
Washington - Mt. Storm
126 mi
MARYLAND
VIRGINIA
WASHINGTON, D.C.
BALTIMORE
N
0
5
10
15
20
25

Figure 1-4. Location of study area in relation to urban areas in eastern Maryland and neighboring states.

More than 30 commercial tree farms covering over a thousand areas are situated in the two-county area, with the majority of these being in Garrett County. An estimated 1 million commercial Christmas trees are currently being grown on these farms for future harvests. Tree growers normally expect to place some 40,000 to 60,000 trees on the market annually; the actual number harvested during the last three seasons (1968-1970) ran well below expectations, however, because of the poor quality of trees on some of the farms.

For the past 20 years, the Maryland Department of Forests and Parks has been engaged in an extensive program of planting trees on abandoned or submarginal farm land for reforestation. Some 1,500 sites with a total of about 17,000 acres have been planted as reforestation areas in Garrett County.[2] Some tree stands started in the 1930's are now providing a return from thinnings for pulpwood. About half of the trees planted were Eastern white pine.

Between 1956 and 1969, approximately 1,200 acres in Grant County were planted for commercial Christmas tree production, strip mine reclamation, and reforestation.[3]

CLIMATOLOGY

The climate of the high plateau region around Mt. Storm, West Virginia, is comparable to that of the northern half of Maine.[4] Red spruce and balsam fir, typically cold-climate trees, are the dominant types of forest growth on the slopes of Cabin Mountain. The protected valleys and the eastern, lower part of the region have a wet continental climate more in keeping with the latitude. Rainfall in the area—generally plentiful throughout the year—ranges from 38 to 50 inches.

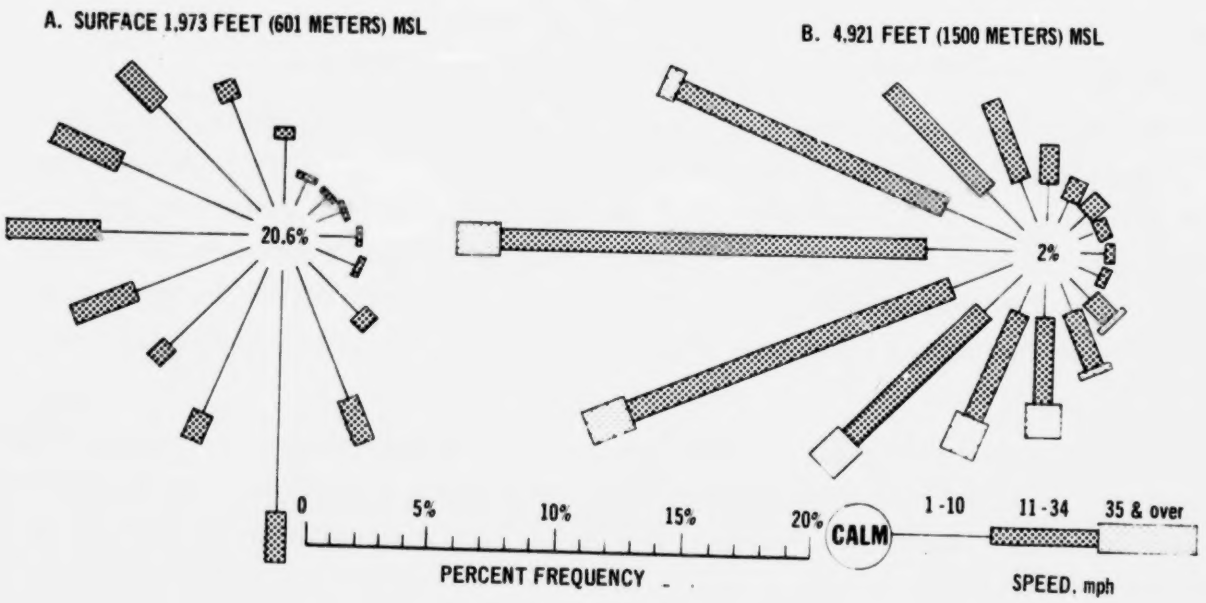
During the colder half of the year, frontal storm systems moving from the west bring most of the precipitation. Occasionally storms moving along the coast 150 miles to the east deposit substantial amounts of rain or snow in the eastern portion of the area, but generally not beyond the crest of Backbone Mountain. In summer most precipitation occurs as showers and thunderstorms in the broad current of moist tropical air from the Gulf of Mexico.

A frost-free season is expected between the first of June and the first of September at the 3,300-foot (MSL) level, whereas 1,000 feet lower in the Oakland, Maryland, region, the period is between May 23 and September 22 during an average year.

Climatological records for the Oakland, Maryland, area, covering the past 70 years, have been used by W. J. Moyer, climatologist for Maryland and Delaware, to compare with the region's weather, principally temperature and precipitation, during the years 1969 and 1970.[5] Mr. R. O. Weedfall, climatologist for West Virginia, has also made such a comparison for the West Virginia portion of the study area.[6]

In general, the climatologists reported that the winters 1968-69 and 1969-70 were colder than normal, and snowfall was greater than usual during both periods. The 1969 growing season began under severe drought conditions, but summer rainfall arrived in time to benefit plant growth. In fact, yields of several field crops (corn, wheat, barley, etc.) were average, or above, for the year. The past two summers (1969 and 1970) in the area have been characterized in the West Virginia Climatological Data Bulletin as being cool and moist with respect to growing conditions, with both years having longer-than-average growing seasons.[7]

In mountainous terrain, both the wind direction and speed are strongly influenced by the particular mountain-valley terrain configuration and orientation. Figure 1-5 shows the wind-rose pattern for Elkins, West Virginia, at the surface and 3,000 feet above the surface. Elkins lies about 40 miles southwest of Mt. Storm in a north-south-oriented mountain valley. The 3,000-foot level above the surface at Elkins is only a few hundred feet above the level of the Cabin Mountain watershed between Elkins and Mt. Storm. Figure 1-5b shows prevailing westerly winds in the flow aloft. In Figure 1-5a, south winds are most frequently observed at the surface, closely corresponding to the orientation of the valley in which Elkins is located. The Elkins wind roses show the normal pattern of lighter winds at the surface than aloft. In fact, the surface winds are unusually light, evidently because of the topographically sheltered location of Elkins.


A. SURFACE 1,973 FEET (601 METERS) MSL

B. 4,921 FEET (1500 METERS) MSL

Figure 1-5. Wind rose of surface and upper-level wind at Elkins, West Virginia, for period 1948 through 1952.

AIR POLLUTION METEOROLOGY

In estimating the transport and dispersion of pollutants over the study area, wind measurements above ridge level were employed instead of surface measurements because the latter are markedly affected by local topography. The transport of effluents from sources at well-exposed, high-ground elevations such as the Mt. Storm Power Plant will be determined primarily by the relatively unobstructed flow above the valleys and ridges.

Emissions from other sources located along river valleys, such as the pulp mill at Luke, Maryland, are confined by local topography so that emissions escape the surface-layer circulation and enter the higher-level flow pattern only through vertical mixing. Ultimately, all of the pollutants that remain in the atmosphere are entrained in the general circulation pattern above the ridges.

Since upper-wind measurements at Elkins were discontinued in 1952, Pittsburgh radiosonde data probably provide the most nearly representative wind data for the Mt. Storm area. Official radiosonde observations of winds, temperature, and humidity aloft are obtained at Pittsburgh as part of a national network of such stations operated by the National Weather Service. Table 1-1 gives Pittsburgh's 5-year mean winds at the 1000-foot level above the surface for the growing season (June-September). For comparison, the corresponding 1970 season winds are also shown in the tabulations. The most notable difference between the two periods is the excess of west winds during 1970. The unusually high frequency of west winds was also reflected in surface-based wind measurements made at two locations in the study area, at the Mt. Storm Power Plant and at Steyer No. 2 Farm. The wind-direction frequencies for these stations are shown in Appendix D.

The Pittsburgh radiosonde data also provide a basis for estimating atmospheric stability in the study area. Radiosonde measurements of the change in temperature with height are used to infer stability, an important factor in dispersing and diluting pollutants. Considering carefully the differences in exposure and elevation, Pittsburgh data provide useful approximations of stability in the study area. Well-exposed locations in the area should have a low-level stability pattern similar to that at Pittsburgh.

In estimating the impact of peak levels of SO_2 on area receptors, primary consideration must be given to the incidence of temperature inversions. Inversions are layers in which temperatures increase with height and are indicative of stable air and poor dispersion conditions. Peak ground-level concentrations from stack effluents are likely to accompany the following inversion-associated conditions:

1. Inversion break-up fumigation — A plume, embedded in an inversion based at or near the surface, undergoes fumigation in mid-morning when surface

Table 1-1. WINDS AT 1000 FEET ABOVE PITTSBURGH AIRPORT
FOR PERIOD JUNE THROUGH SEPTEMBER
COMPARED FOR 5-YEAR BASE PERIOD AND 1970

Direction	Occurrence, %		Mean speed, mi/hr	
	1960-64	1970	1960-64	1970
N	5.8	7.1	11.6	10.3
NNE	5.1	3.8	11.2	9.2
NE	3.3	4.2	9.4	9.2
ENE	4.3	1.4	9.6	8.1
E	2.7	1.8	11.4	10.3
ESE	3.2	1.9	11.4	9.2
SE	4.2	6.7	11.2	11.4
SSE	3.7	3.0	11.9	11.6
S	3.3	2.9	13.9	10.3
SSW	6.7	9.1	14.1	13.9
SW	11.9	12.6	15.2	15.0
WSW	11.4	10.1	16.6	16.1
W	11.0	16.7	15.7	17.2
WNW	8.9	6.2	14.6	16.1
NW	7.2	6.2	13.4	12.5
NNW	6.4	5.7	13.7	12.8

heating dissipates the inversion through plume height and the effluent is mixed to the ground. Such fumigations generally last for 30 to 45 minutes, occasionally longer. Because inversion break-up fumigations over an area tend to be random, any particular location is affected only occasionally.

2. Limited mixing — The plume is inhibited from mixing upward by a persistent inversion or stable layer aloft and is dispersed to the surface with resulting high ground-level concentrations. Although generally less frequent than inversion breakup, limited mixing conditions may persist for periods of from a few hours to a few days. Limited mixing is especially relevant to effluents from tall stacks of large power stations. Power station stacks are often designed to carry effluent plumes above low-level surface-based inversions, but not above stable layers situated aloft. Such plumes are thus trapped and confined within the limited mixing layer beneath.

Hosler,[8] using radiosonde data, estimated the low-level inversion frequency for several locations in the United States. A summary of inversions based at or below 500 feet for Pittsburgh is shown in Table 1-2. Such inversions are estimated from

Table 1-2. PERCENT FREQUENCY OF INVERSIONS WITH BASES ≤500 FEET, PITTSBURGH, PENNSYLVANIA, JUNE 1955 THROUGH MAY 1959[8]

	Time of day (EST)				Total time
	0700	1000	1900	2200	
Winter	41	24	20	33	24
Spring	68	6	5	34	31
Summer	64	1	4	55	27
Fall	62	15	25	56	34
Annual	59	12	14	45	29

observations to occur 29 percent of the time. Seasonally, they range from 24 percent in the winter to 34 percent in the fall. Of greater significance, however, is the incidence of early morning inversions in the spring and summer. At 7 a.m. EST, inversions occur on 68 percent of the spring and 64 percent of the summer days. Particularly during these seasons, low-level inversions nearly always dissipate or break up between 7 a.m. and 10 a.m.

In another study, Holzworth[9] summarized the persistence and frequency of episodes of limited mixing at heights to 2,500 feet and mean layer wind speed limited to 13.5 miles per hour by means of radiosonde data. A summary of Pittsburgh data is shown in Table 1-3. The table shows that episode conditions are most persistent in fall and winter. A sizable portion of these persistent cases are likely to be limited mixing cases. In spring and summer, episodes are least persistent. In summer only 4 of 324 cases persisted for 12 hours or more; this indicates that nearly all cases are likely to have occurred in the morning, and dissipation subsequently occurred due to intense daytime heating. Therefore inversion breakup is indicated to be the predominant critical dispersion condition in summer. The 324 cases would represent nearly 70 percent of the total summer cases.

Table 1-3. PERSISTENCE AND FREQUENCY OF EPISODES OF MIXING HEIGHT ≤ 2500 FEET AND WIND SPEED ≤ 13.5 MPH, PITTSBURGH, PA., 1960 THROUGH 1964 (NCC TABULATIONS)[9]

	Duration, consecutive hr								N[a]
	12	24	36	48	60	72	84	96	
Winter	30	12	6	4	4	2	2	1	176
Spring	8	3	0	0	0	0	0	0	205
Summer	4	1	0	0	0	0	0	0	324
Fall	13	9	1	1	1	0	0	0	285

[a] Column N lists the number of cases in which criteria were met without regard to consecutiveness.

The data presented in Tables 1-2 and 1-3 strongly indicate that some critical inversion condition, either inversion breakup or limited mixing, occurs on a high percentage of days during the growing season. In summer, it is estimated such conditions, primarily inversion breakup likely accompanied by fumigations, occur in the study area on about one-half to three-fourths of summer days.

BLANK PAGE

IV. ASSESSMENT OF TREE DAMAGE

AIR POLLUTION-RELATED TREE INJURY

Air pollution damage to vegetation has been observed since the late nineteenth century, particularly damage to crops and forest lands near large pollution sources. In recent years, evidence has rapidly accumulated that suggests that damage from air pollution is sufficiently widespread to rank this cause with other traditional causes, such as bad weather and harmful insects, as a chief plunderer of crops and trees.

Damage to citrus trees and other hardwoods and softwoods has been described and a number of studies of injuries associated with specific pollutants have been made. The body of literature associated with these studies is voluminous and is extensively reviewed elsewhere.[10] As background for subsequent discussions, a brief review of directly pertinent information is presented here.

Studies of Conifer Damage

Conifers, because of their year-round foliage, are generally more susceptible to air pollution than hardwoods. Conifer needles are normally retained for several growing seasons, during which they perform the photosynthetic functions essential for tree growth. Thus, cumulative damage to and premature loss of needles are thought to have a relatively greater impact on the growth of conifers than on hardwoods, which are deciduous—that is, the leaves are completely replaced annually.

Several documented studies show that pine trees are susceptible to injury from low concentrations of sulfur dioxide (SO_2), ozone (O_3), and other pollutants.[11,12,13]

Sheffer and Hedgcock[14] report that with moderate dosages of SO_2 the older needles of conifers tend to become chlorotic (yellow) and to drop off prematurely (premature abscission). Eastern white pine and Scotch pine are especially susceptible to SO_2 damage.

Healthy but dwarf-susceptible Eastern white pines manifest tip burn and banding when exposed to low concentrations of SO_2 and O_3.[15] New foliage in its vigorous growth stage is most susceptible to this type of injury. In White pine, concentrations of SO_2 in the 0.01 to 0.15 ppm range for 2 hours can cause injury to new foliage and ozone at a concentration of 0.25 ppm for 2 hours can cause needle necrosis. In susceptible grafted seedlings, acute symptoms may even be produced by O_3 or

PRECEDING PAGE BLANK

SO_2 at concentrations of less than 0.05 ppm over a 3-hour fumigation. The susceptibility of certain plants to ozone and sulfur dioxide is enhanced when the two gases are present simultaneously[16] and this synergism may apply to conifers as well.

Linzon[17] noted that banding and excessive needle drop may be produced by long-term exposure to low concentrations of SO_2. These phenomena have been reported for locations where the mean annual concentration of SO_2 in ambient air is below 0.03 ppm. Reports of deteriorated vegetation in areas polluted by sulfur dioxide[18,19] make it clear that injury can occur where annual average concentrations are quite low, even when the sources of pollution and/or the meteorological conditions are such that the injury threshold is exceeded only occasionally. For example, growth suppression and, particularly, chronic injury have been shown to occur where concentrations of SO_2 never exceed 0.1 ppm.[20]

In Eastern Tennessee, mortality of Eastern white pine has occurred from a disease called post-emergence chronic tip burn. The disease has been noted only in industrial areas, generally within about 20 miles of plants producing substantial stack emissions. Convincing evidence indicates that air pollutants are the causal agents. Although some investigators consider SO_2 to be the most likely cause of the disease, others attribute it to repeated or continuous low-level fumigations with some other unidentified gas or gases produced in the affected area. Whatever the causal agent may be, some Eastern white pines are so sensitive to it that trees located many miles from the pollution source develop striking foliage symptoms.[21]

Complicating the diagnosis of air pollution damage to vegetation are the problems associated with measuring the minute concentrations of contaminants involved, the possibilities of synergistic effects, the delay in onset of symptoms, the demonstrated existence of genetic differences within species, and the frequent production of similar injury symptoms by insects, bacteria, fungi, and viruses. Further, the modifying effects of climate—that is, rainfall, temperature, and wind—are often difficult to assess. In spite of these complications, an experienced observer can frequently diagnose the existence of air pollution damage with confidence.

Conifer Injury Symptoms

Air Quality Criteria for several pollutants have been published by the National Air Pollution Control Administration (now the Air Pollution Control Office). Air Quality Criteria for Sulfur Dioxide[22] and Air Quality Criteria for Photochemical Oxidants[23] contain a summary of current scientific knowledge of the effects of these pollutants on vegetation. The descriptions of vegetation injury as presented in these documents are useful in categorizing the types of damage that may be expected in conifers.

The visible symptoms of air-pollution-related injury to conifers may be classified as acute, chronic, and physiological.

Acute injury is associated with high concentrations over relatively short intervals and usually occurs in conifers as discolored bands on the tips of the needles. The injured needles change from the usual dark green to a lighter green, and the areas actually injured turn yellow-brown and then red-brown, resulting in a banded appearance. The discoloration in conifers may involve the whole needle or limited areas of any portion. Abscission (loss of needles) may follow after some interval so that the affected trees are often deficient in needles.

The development of chlorosis (the gradual yellowing of needles symptomatic of chronic injury) from sublethal concentrations of pollutants may require several days or weeks. The slow fading of green color over a period of several days suggests that the chlorophyll-making mechanism is being destroyed and that this pigment, essential to photosynthesis, cannot be replenished. Although chlorosis is a common and nonspecific symptom in plants, often indicative of some nutrient deficiency, the chlorosis caused by air pollution can sometimes be distinguished, because of the gross pattern of damage, from that caused by other agents. Microscopic examination of the leaf's cellular structure also helps distinguish pollutant-caused damage from naturally caused damage.

A third kind of plant damage manifests itself as alterations in growth patterns. Presently there are few distinctive alterations that can be attributed to a specific air pollutant, although generally poor growth is a very real effect in some cases. Certain growth abnormalities will undoubtedly come to be associated with specific gases as future studies are carried out.

When visible symptoms of injury, such as acute lesions, chronic chlorosis, or excessive needle abscission occur, growth or vitality of the tree may be affected. Some investigators have suggested that suppression of growth may also occur in long-term low-concentration exposures even if visible symptoms of foliage injury do not develop.[24]

CHRISTMAS-TREE FARMS

Christmas-tree growers in the Mt. Storm area became concerned with the declining quality of their trees in 1968.[25] Excessive browning of needles was the first symptom noticed by two growers, Dr. F. D. Custer, owner of Mountaintop Tree Farms, and Mr. V. T. Steyer, owner of Steyer Tree Farms, at their farms near Mt. Storm, West Virginia, and Kitzsmiller, Maryland.

Prior to 1968, these two men had grown Christmas trees commercially in this locality for more than a decade without encountering any unusual problems. In fact, the growers had consistently raised trees of premium quality much in demand by commercial buyers. Figure 1-6 is a photograph taken in 1964 of near-perfect Eastern white pine growing on a Steyer Farm that subsequently produced award-winning trees.

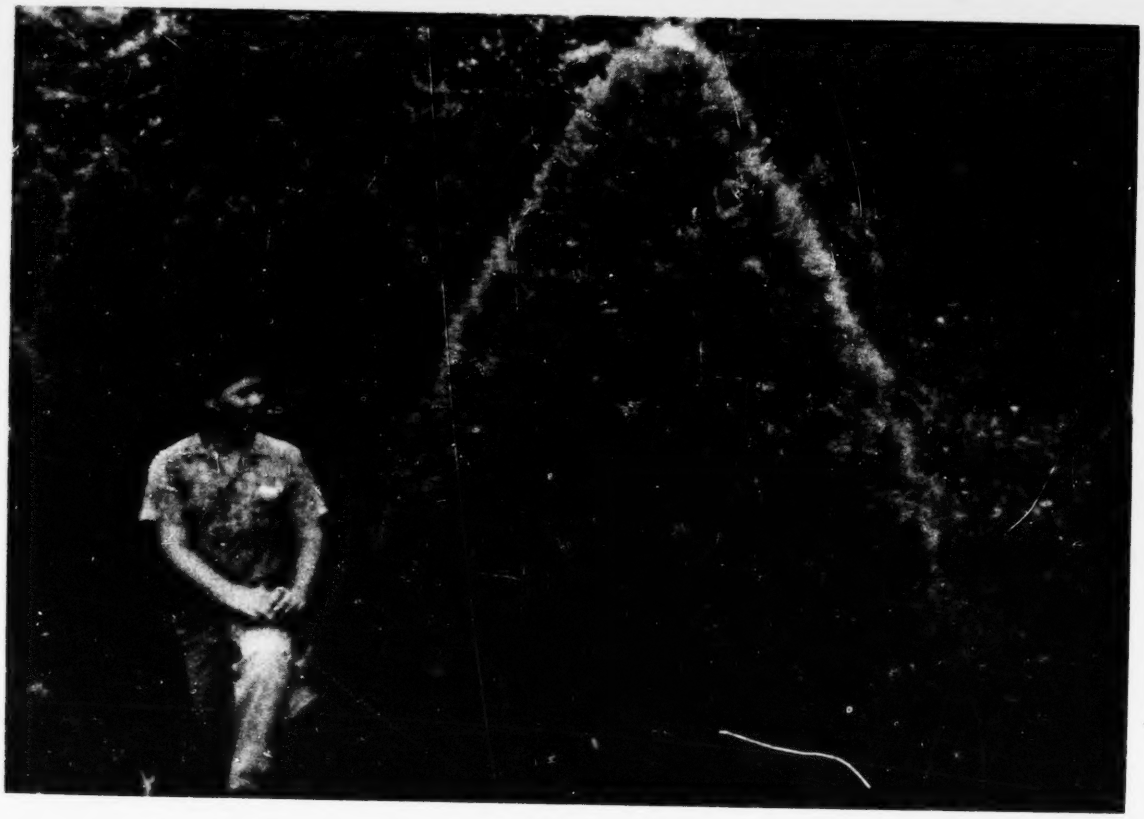


Figure 1-6. Photograph of premium-quality Eastern white pine growing on Steyer Farm, 1964.

These growers found that some of their trees were showing, in addition to needle browning, the abnormal growth symptoms that were to increase in severity and number in subsequent growing seasons. Among these abnormalities were premature abscission, lack of lateral side growth, and irregular branch and needle development. Trees thus affected took on a sparse, ragged appearance that rendered them undesirable as ornamentals or Christmas trees.

The severity of this damage to the Christmas trees, as viewed by the growers, increased with proximity of the farms to the Mt. Storm power plant. Stony River Farm, which is in Grant County, West Virginia, only 2.5 miles from the power plant, exhibited the most severe damage. Trees on farms farther away from the power plant on the opposite side of Backbone Mountain in Maryland remained generally healthy, although some injury to Eastern white pine has been reported throughout that area.

During 1969 and 1970, the area farms were examined and studied by many experts from APCO as well as from various universities and state agencies. Their reports form an impressive body of literature from which much of the information presented in this document has been abstracted.[26-31]

Injury Classification

A variety of tree injuries have been noted in the Mt. Storm studies. The diversity of the injuries observed suggests strongly that they cannot be ascribed to any one toxicant or other cause. In order to identify them clearly, the various types of injury found are described in this section.

Tip Burn or Tip Necrosis - Tip burn, an acute injury symptomized by "burning" and browning of the needle tips, has been closely identified with the exposure of conifers to SO_2 as well as O_3 and fluoride. This injury has been seen on nearly all conifer species growing in the area, but most often on Eastern white pine, Scotch pine, and Austrian pine. The injury varied in severity from slight tip browning and banding to death of the needles. Tip burn was more prevalent in the 1969 growing season than in the 1970 season, when it occurred mainly on the more sensitive species, Eastern white pine and Austrian pine.

Chlorosis - This chronic condition, indicated by the yellowing of needles, can be caused by nutritional or hormonal deficiencies but, in sensitive pines, it can also be induced by exposure to O_3 and SO_2. Eastern white pine is particularly sensitive. Chlorotic needles and chlorotic banding of needles were observed on this species throughout most of the study area. The "chlorotic dwarf" symptoms on White pine are not uncommon throughout the Eastern United States. In this injury, yellowing of needles is accompanied by stunted growth and sparse foliage.

Early Needle Drop (Early Abscission) - Needles were shed prematurely by the conifers that suffered some form of injury. Green needles on two- and three-needle pines (Scotch, Virginia, and Austrian) are normally retained 3 years. The normal retention for five-needle pine (Eastern white) is 2 to 3 years, depending on the moisture level in the habitat. Chlorotic needles, or prematurely necrotic needles (as distinct from normal senescence necrosis), were frequently shed by the affected trees in the Mt. Storm area, and the resulting reduction in foliage gave the trees a sparse or bare appearance. Early needle drop has been observed on nearly all of the farms in the area.

Random Short Needles - This form of injury to conifers was first observed in the Mt. Storm area but, now that it has been described, it is being found in other parts of the country. A healthy conifer has needles of a length characteristic of the species; that is, the length of the needles on a tree varies only minutely. Trees with the "long-short needle" syndrome, however, have randomly distributed short or long needles. The short needles vary in length from one-tenth normal to normal length, with most being shorter than one-half normal length on severely damaged trees. Sometimes only one needle in a fascicle is shortened, sometimes all of them are shortened, with the needles in the adjacent fascicle being normal. At other times, abnormally long needles are found on a twig that also has normal and short needles. An extreme example of random needle dwarfing seen consisted of needles that never quite emerged from the fascicle. Dwarfed needles were observed to be more susceptible to early abscission.

The long-short needle syndrome was found predominantly on Scotch pine, although it was present to some extent on all pines. The trees affected have such a rough, ragged appearance that they are unmarketable.

Twisting and Elongation of Needles - A variation of the "long-short needle" syndrome occurs in which one surface of the needle grows faster than the other, causing the needle to bend and curl. If the top surface of the needle grows faster than the lower surface (epinasty), the needle bends down. Conversely, if the lower surface grows faster than the upper (hyponasty), the needle bends up. Examples have been found in which the needles formed a right angle.

Bud Failure - Conifer buds are normally formed at the end of branches, and new branches and needles grow from them the following year. If the buds fail to open, then, normal growth does not occur and the trees become stunted and malformed. Sometimes bud failure results in excessive growth from the surviving buds.

A number of variations in the bud-failure syndrome have been observed on the farms. Sometimes the main axial terminal buds develop but the sub-terminal buds fail, which results in a long scraggly leader that must be cut back. Sometimes the lateral terminal buds and the lateral sub-terminal buds fail. Trees with any of these combinations of bud failure are loose and open-branched, and are frequently lacking in foliage.

Failure of the sub-terminal buds to develop on both the main axial terminal and the lateral side branches seriously affected the growth of Scotch pine and spruce at some of the more severely damaged farms. This growth aberration does not seem to occur on other pine species or on fir.

Adventitious Budding - In adventitious budding, an excessive number of buds form, usually at branch terminals but in other positions on the branches as well. The normal number of buds on a terminal cluster on unsheared pine is four to six. As many as 9 to 31 buds appeared on some of the trees, with additional sub-terminal buds occurring on stems immediately below the terminal cluster. A few of the trees even had compound buds on the main terminal, some having as many as six main buds, each with a crown of three to seven buds. This bizarre growth appeared only at a few farms and is a phenomenon not encountered before.

Brooming of needles (numerous fascicles in close proximity to each other) was observed at a few farms, where it affected Scotch pine and Eastern white pine.

Basal Spotting of Needles - In this injury, small necrotic spots occur at the extreme base (inside the sheath) of living needles. The spots are located on the outside of the needles next to the basal sheaths and between the needles composing each fascicle. These dead spots are present on most of the pine needles growing on the more severely affected farms. Needles that showed random dwarf symptoms were highly inclined to basal spotting. Basal spots were sometimes observed on some of the seemingly healthy needles of normal length, but less frequently than on short needles.

Damage Survey

In connection with the APCO study, several visits were made to the Christmas-tree farms in Garrett and Grant Counties. Two surveys of damage were made in the last 4 months of 1969 and five were made in the 1970 growing season. During the surveys, attention centered on farms where damage was most severe, although other farms were inspected to determine the geographical distribution of the damage.

During these surveys, Christmas trees and indigenous vegetation were examined for possible damage by plant diseases, sulfur dioxide and other pollutants, and other etiologic agents. Vegetation samples were collected for chemical, morphological, and microscopic analysis.

The first inspection of tree farms for injury in September and November of 1969 revealed a complex pattern of symptoms. Injury typical of sulfur dioxide fumigation was readily observed as were a variety of growth aberrations for which the cause and extent could not be readily defined. A more extensive inspection schedule was then carried out during the 1970 growing season.

Observations as to the nature and extent of tree damage are presented in Table 1-4. Brief factual data on the farms are also given and are keyed by identifying numbers to the map in Figure 1-7.

The injuries observed on the tree farms have been previously classified according to a number of distinct symptoms. For our discussion of the possible causes of the damage and the extent to which it occurred, the various symptoms can be grouped into two broad categories:

1. Injury affecting needle tissue, such as tip burn, banding, chlorosis, or other symptoms of air pollutant damage.
2. Various growth alterations, such as early needle loss, bud failure, short- and long-needle syndrome, and other symptoms previously listed that are not generally typical of air pollutant damage.

Table 1-4. SUMMARY OF DAMAGE ON TREE FARMS

Farm description	Damage description
1. Stony River Farm Located 2-1/2 miles NW of Mt. Storm plant; consists of 170 acres of Scotch pine, Norway spruce, and a few Austrian pine and Eastern white pine.	1969 Trees were severely affected by abnormal growth symptoms. Long-short needle syndrome and early needle loss were prevalent on Scotch pine and white pine. Norway spruce and Scotch pine showed extreme lateral bud failure. Variety of other growth symptoms adventitious budding, needle "brooming," and crooked needles were manifested on Scotch pine. Slight tip burn appeared on Austrian pine and Scotch pine. Severe tip burn showed on red pine and white pine growing in reforested area near farm. Indigenous vegetation also showed injury characteristic of SO_2 fumigation.
	1970 Trees throughout farm were generally in advanced state of decline. Majority of Scotch pine were affected by long-short needle syndrome and had only 1 year needles, which gave them a ragged and bare appearance. Although only a trace of tip burn was observed on the farm in 1970, trees exhibited such extremely poor appearance that nearly all were considered unsaleable.
2. VEPCO Experimental Farm (formerly Steyer No. 1) Located 7 miles NW of Mt. Storm plant (east slope of Backbone Mountain); consists of 25 acres of Scotch pine, Eastern white pine, and a few Norway spruce.	1969 Tip burn, discoloration, and banding were observed on many Scotch and white pine. Scotch pine experienced growth alterations, long-short needles, and lateral bud failure, but to a lesser degree than at Stony River Farm. White pine had started to decline, showing yellowing of needles, early needle loss, and chlorotic dwarf symptoms. Squash planted as an indicator of air pollution damage showed typical SO_2 injury.
	1970 VEPCO engaged in experimental spray program on 40% of tree stand to determine whether damage was related to insect infestations.[32]
3. Steyer No. 5 Farm Located 10 miles N of Mt. Storm plant (east slope of Backbone Mountain); consists of 50 to 70 acres of Eastern	1969 Widespread injury was observed on all pine species. Severe tip burn was present on a number of trees. Long-short needle syndrome affected Scotch pine, Virginia pine, and some of the white pine. Premature shedding of needles was especially

Table 1-4 (continued). SUMMARY OF DAMAGE ON TREE FARMS

Farm description		Damage description
white pine, Virginia pine, Scotch pine, and Norway spruce.		noticeable. White pine had deteriorated badly and had begun to show pronounced chlorotic dwarf symptoms.
	1970	Condition of the farm remained essentially as observed the previous year. Tip burn was not particularly noticeable, with only a slight burn appearing on a few trees. All of the trees have declined to the point where they are not saleable.
4. Steyer No. 4 Farm Located adjacent to Steyer No. 5 Farm; consists of 13 acres of scotch pine with some Eastern white pine.	1970	A stand of high-quality, large white pine trees grown for ornamental stock had started to decline and lose foliage. The 1969 needle growth that showed severe tip burn and chlorosis were shedding prematurely by mid-summer.
5. Steyer No. 3 Farm Located 12 miles NNW of Mt. Storm plant (west slope of Backbone Mountain); consists of 10 acres of Eastern white pine.	1970	The farm has reportedly in the past produced exceptional high-quality white pine trees. Some of the trees were still of high quality and had near-perfect shape. Other trees, however, were beginning to lose color and exhibit thin foliage. Definite tip burn was observed on a few trees and chlorotic dwarf symptoms were becoming noticeable.
6. Steyer No. 2 Farm Located 12 miles N of Mt. Storm plant (east slope of Backbone Mountain); consists of 40 acres of Scotch pine, Eastern white pine, and Norway spruce, with some Douglas fir and Frazier fir; 1 acre of seedlings.	1969	Extensive tip burn was evident on large portions of a Scotch pine field in November. The trees were unharmed only a few weeks earlier. 1- and 2-year pine seedlings in a nearby bed were also severely burned at the same time. The type of injury and the manner in which it occurred indicated that a SO_2 fumigation involving relatively high concentrations had probably occurred. In contrast to the acute injury seen in pines, Norway spruce on this farm exhibited chronic failure of sub-terminal buds on both lateral and axial branches. Trees were loose, oper-branched, and frequently of grotesque shape. Earlier years' growth on the same trees appeared normal, which suggests that the onset of the abnormal growth was in recent years.

Table 1-4 (continued). SUMMARY OF DAMAGE ON TREE FARMS

Farm description	Damage description	
	1970	No evidence of fresh tip burn on the Scotch pine was observed. Seedlings that were severely damaged by tip burn in 1969 never fully recovered and were stunted and unsaleable. Long-short needle syndrome appeared on current growth of Scotch pine affected by tip burn in 1969. Needles severely burned in 1969 were being prematurely lost. Norway spruce continued to be severely effected by bud failure.
7. Taylor Farm (Kempton Road) Located 9 miles NW of Mt. Storm plant (east slope of Backbone Mountain); consists of 21 acres with alternate rows of Eastern white pine and Scotch pine and a few Norway spruce on the periphery.	1969	Banding and yellowing of Scotch and white pine needles were observed and a few needles show tip burn. White pine was affected more than the Scotch pine. There was little evidence of abnormal growth symptoms in either species.
	1970	Chlorosis of current needles and early needle loss on Eastern white pine was prevalent. The trees were thinly needled, holding only one-year needles. Some chlorotic dwarfs were seen.
8. Taylor Farm (Shady Dell) Located 11 miles NW of Mt. Storm plant (west side of Backbone Mountain); consists of 22 acres with alternate rows of red pine and Eastern white pine.	1969	Trees were generally in good condition. A few white pine showed tip burn and chlorosis, but the red pine were unaffected.
	1970	Farm remained in good condition with no observable change. The farm was the least affected of any of the farms in the area.
9. Custer Home Farm Located 17 miles NW of Mt. Storm plant and 16 miles ESE of Albright power plants; consists of 60 acres of Scotch pine, Eastern white pine, red pine, Austrian pine, and Norway spruce.	1969	Austrian pine on exposed hilltop showed tip burn and a few Scotch pine showed yellow banding on current needles. Chlorotic dwarfs of Eastern white pine were scattered throughout the farm.
	1970	The tip burn on the Austrian pine was more severe but otherwise the conditions were the same. Trees on this farm are generally thriving, high-quality trees.

Table 1-4 (continued). SUMMARY OF DAMAGE ON TREE FARMS

Farm description	Damage description
10. Weise-McDonald Farm (near Deep Creek Lake) Located about 18 miles from the Mt. Storm and Albright plants and Luke pulp mill; consists of 35 acres of Scotch pine and some Norway spruce.	1969 Trees appeared healthy without any visible signs of damage.
	1970 Evidence of slight tip burn and long-short needle syndrome had appeared in limited areas of the farm.
11. White Face Farm Located 25 miles N of Mt. Storm plant and 16 miles NE of Albright Power plant; consists of 90 acres of White pine and a few red pine and Norway spruce.	1970 Tip burn and chlorosis were common on the current needles of white pine. A few trees were severely burned but most were slightly to moderately affected. Chlorotic dwarfs of varying size and shape were present throughout the field.
12. Dr. Feister Farm Located 22 miles NW of Mt. Storm Plant and 14 miles SW of Albright Power plant; consists of 40 to 50 acres of Eastern white pine.	1969 Trees appeared reasonably healthy and exhibited normal growth.
	1970 Excessive yellowing of the foliage was noted, with needles being prematurely shed. Deterioration of the trees affected quality and was said to have significantly reduced the number of trees sold.

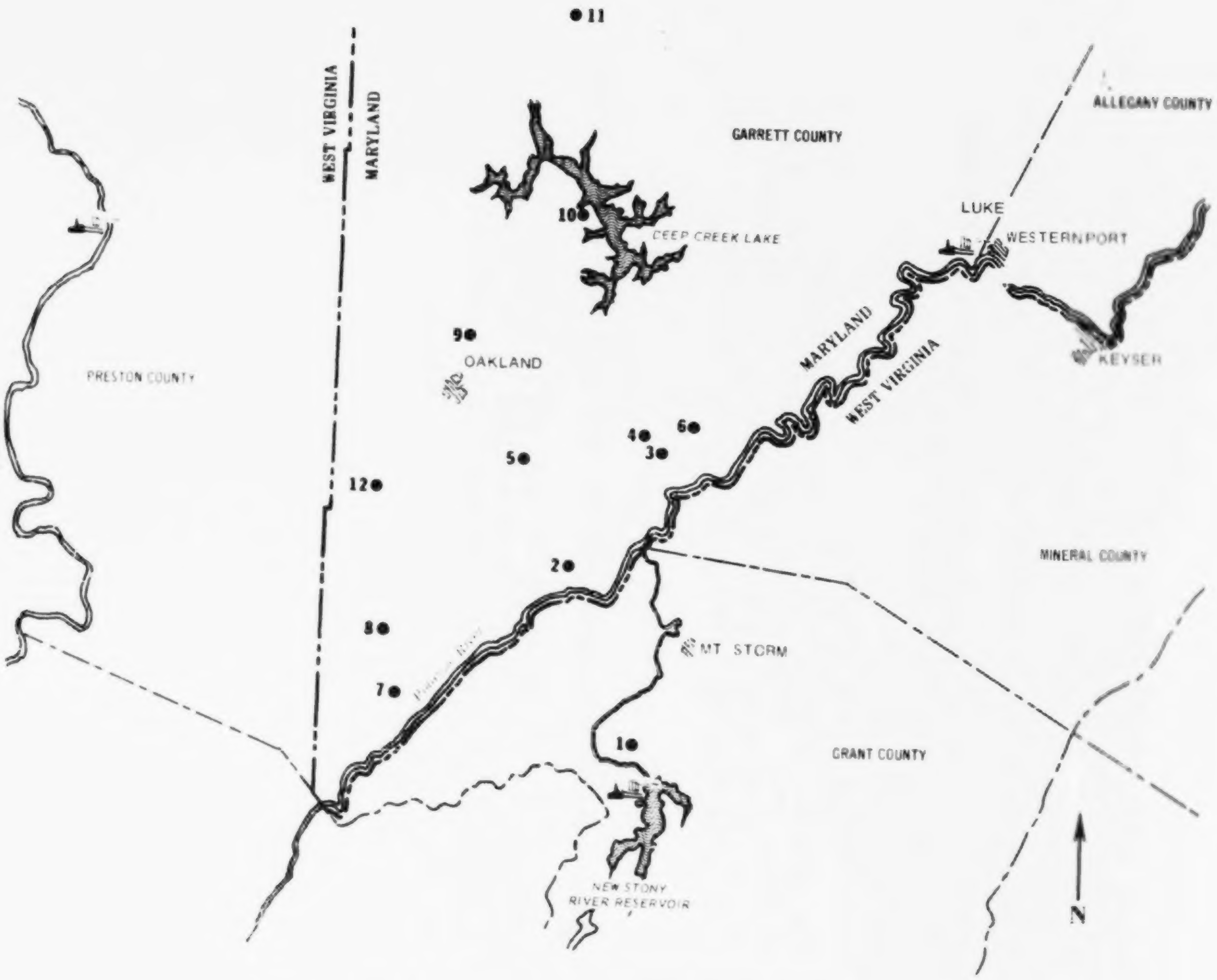

11
WEST VIRGINIA
MARYLAND
GARRETT COUNTY
ALLEGANY COUNTY
10
DEEP CREEK LAKE
LUKE
WESTERNPORT
KEYSER
9
OAKLAND
PRESTON COUNTY
MARYLAND
WEST VIRGINIA
4
6
3
5
12
2
MINERAL COUNTY
8
MT STORM
7
1
GRANT COUNTY
NEW STONY RIVER RESERVOIR
N

Figure 1-7. Location of tree farms surveyed for damage.

Early needle loss could be placed in either category since premature abscission of severely injured needles is frequent whether the injury was caused by chemical (air pollution) burn, harmful organisms, or natural stresses.

As commonly observed on damaged trees in the Mt. Storm area, an abnormal growth symptom is often accompanied by other symptoms on the same tree. For example, several types of injury have appeared on the branch of a Scotch pine growing at the Stony River Farm (Figure 1-8). On this branch, which is typical of those on many of the trees on this farm, the combined effects of early needle loss (only 1-year needles still present by late summer), lateral bud failure (lacking normal complement of side branches), and random dwarfing of needles are all present. The pattern shown here is sufficiently common that the individual growth aberrations are frequently referred to as the "abnormal growth symptom complex."

As mentioned earlier, the damage that now affects trees on a number of farms in the area first appeared at the Stony River Farm. The location of this farm in relation to the Mt. Storm Power Plant is shown in Figure 1-9. When inspected in

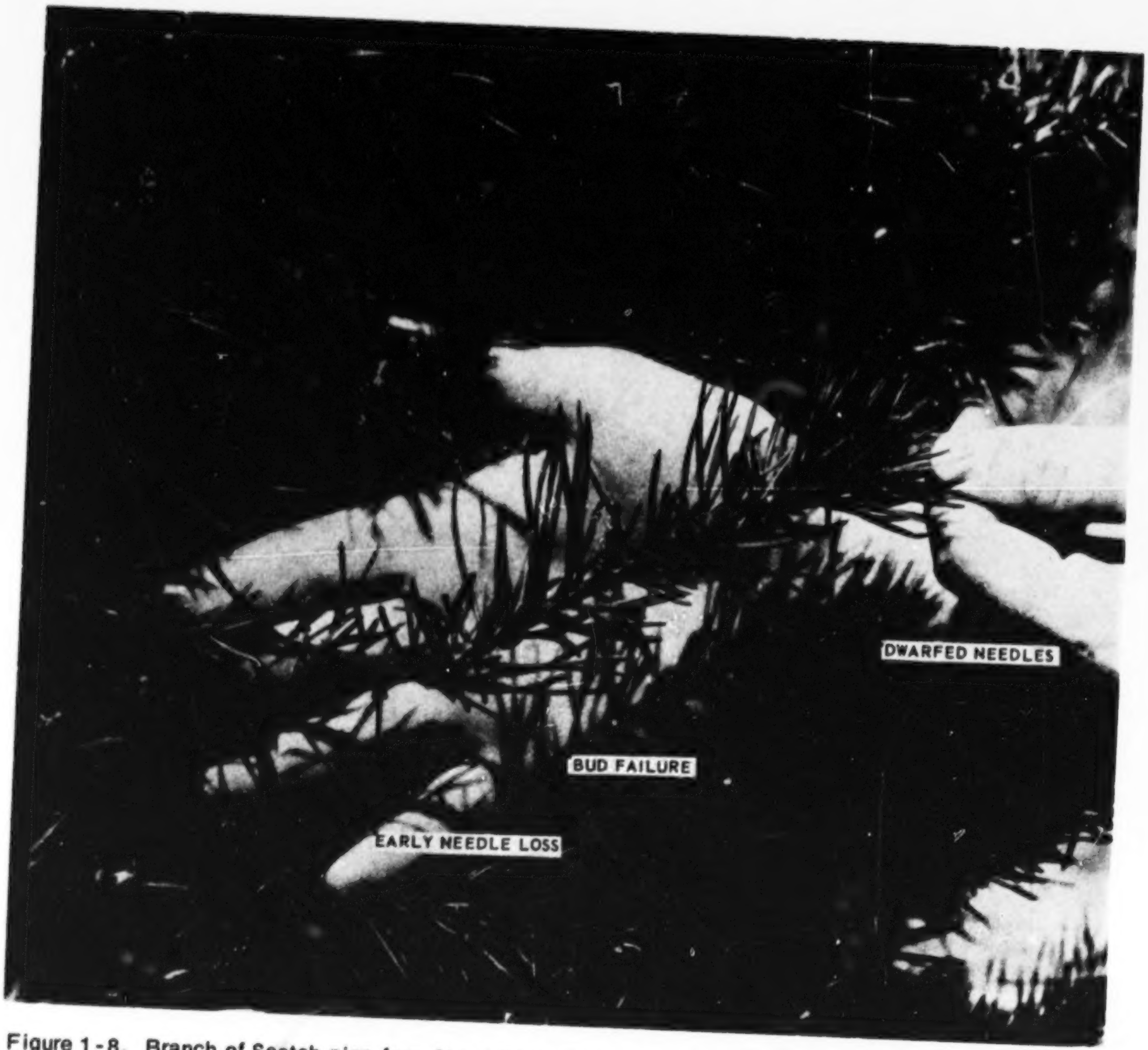


Figure 1-8. Branch of Scotch pine from Stony River Farm showing three types of abnormal growth symptoms: early needle loss, lateral bud failure, and random dwarfing of needles.

1969, trees on the Stony River Farm, as well as on several other tree farms on the southeastern slope of Backbone Mountain, showed extensive damage. The damage at the Stony River Farm is principally a manifestation of abnormal growth symptom complex. At the Steyer Farms (Nos. 1, 2, 4, and 5), 8 to 12 miles from the power plant in Maryland, growth aberrations were also prevalent but to a lesser extent than at the Stony River Farm.

Figures 1-10a and 1-10b show a Norway spruce, on the Steyer No. 2 Farm, that was severely affected by bud failure, and a high-quality spruce of the same variety on the Custer Home Farm near Oakland. On the northwestern slope of Backbone Mountain, and further north, Christmas-tree farms have not been noticeably affected by the abnormal growth symptom complex.

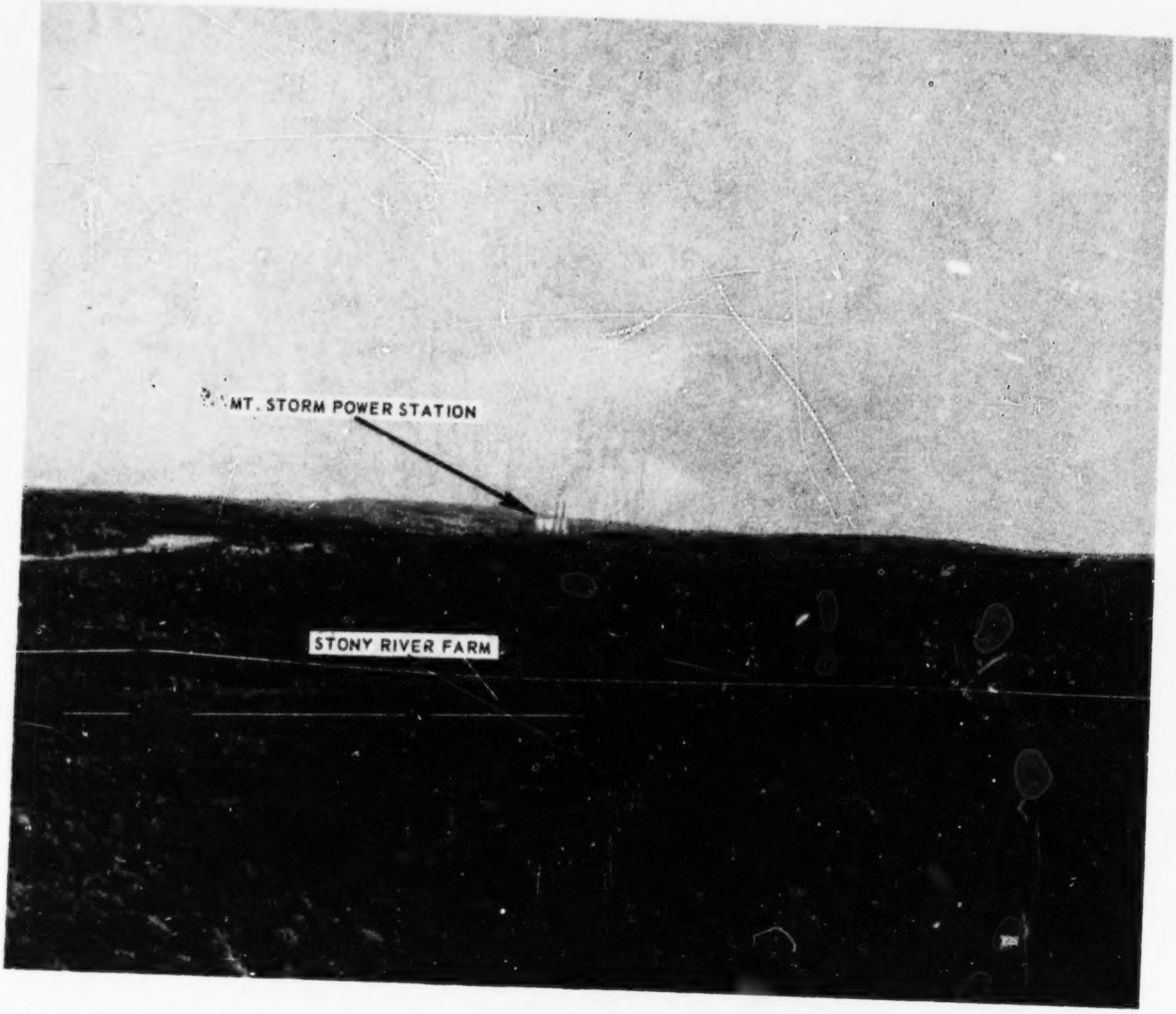


Figure 1-9. Aerial photograph showing proximity of Stony River Farm (foreground) to Mt. Storm River Power Plant.

Needle burn was also observed on several farms in the area during the 1969 growing season. Severe tip burn and banding occurred on a variety of conifer species at those farms nearer to the Mt. Storm plant. The burn was sufficiently typical of sulfur dioxide injury to leave little question as to the causative agent.

Incidents of severe tip burn, except on those farms where Eastern white pine and Austrian pine are grown, were not observed or reported by the growers on farms located northwest of Backbone Mountain. The presence of needle burn on Austrian pine on the upper elevations at the Custer Home Farm, and of tip burn on white pine at White Face Farm (at the northern end of Deep Creek Lake), also at a higher elevation, suggests that SO_2 emissions from sources other than the Mt. Storm Power Plant may be contributing to the area's problems. It is significant that damage to white pine was noted at farms many miles from the Mt. Storm plant. Relevant

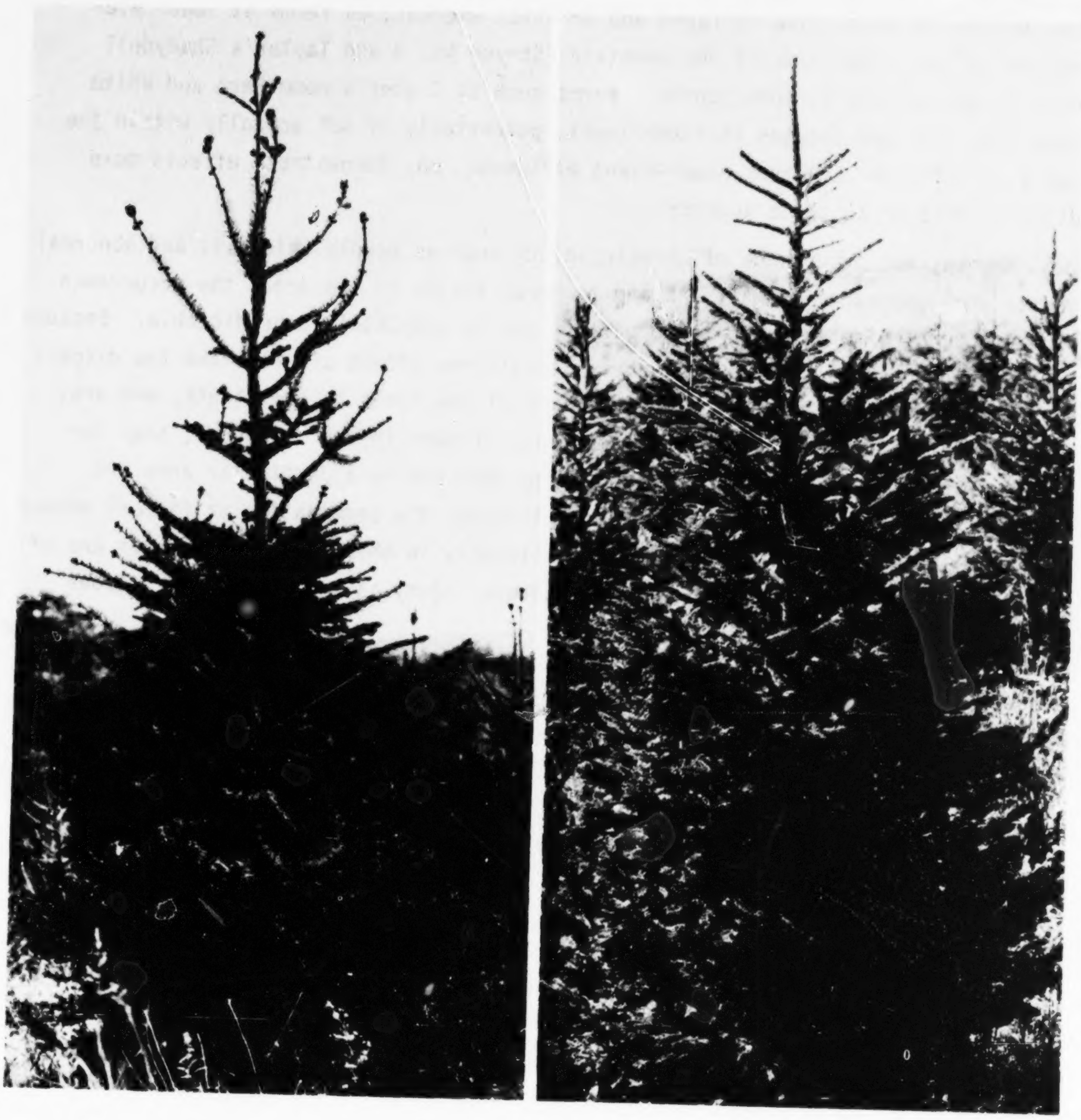


Figure 1-10. a. Damaged spruce at Steyer Farm. b. Normal spruce at Custer Home Farm.

sulfation and oxidant data are presented in later sections.

The inherent sensitivity of Eastern white pine to both sulfur dioxide and oxidants makes it difficult to assess the relative effects of these pollutants on this species. The possibility that one pollutant enhances or aggravates the effects of the other complicates the diagnosis in this species of oxidant and SO_2 injury. Proximity to the Mt. Storm Power Plant appears to have at least a limited effect on the damage seen in white pine. On farms along the Potomac River on the southeastern slope of Backbone Mountain (Steyer No. 5 and Taylor's Kempton Farm), the decline of white pine is rapid and drastic; whereas, on farms at lower elevations on the other side of the mountain (Steyer No. 3 and Taylor's Shadydell Farms), the decline is more subtle. Farms such as Custer's Home Farm and White Face Farm that are located at ridge level, potentially if not actually within the realm of influence of other power-plant effluents, may demonstrate effects more directly related to these sources.

Whereas the occurrence of chronic injury such as needle chlorosis and abnormal growth show geographical patterns and temporal trends in the area, the occurrence of acute burn episodes exhibits no pattern and is completely unpredictable. Because local topography and overall atmospheric conditions affect air flow and the dispersion of pollutants, they affect the exposure of the trees to pollutants, and are, therefore, critical factors in the occurrence of burn injury. As such, they can result in wide variations in the tree damage observed in a particular area and even on the same farm from year to year. Although the combination of factors needed to produce needle burn may occur only occasionally in the area, the episodes are of special importance to the grower because severe injury is inflicted on the trees when they do occur.

The tree injury incident observed at the Steyer No. 2 Farm in November 1969 illustrates how serious this problem is to the growers. The acute needle burn injury that occurred to an entire field of Scotch pine at this farm over a short time period is highly indicative of an SO_2 fumigation. The resultant damage was readily discernible, with some of the trees having a scorched appearance on one side and others on all sides of the tree. Results of histological examinations of the injured needles taken from these trees are presented later.

Severe burn symptoms appeared in nursery seedling beds on the Steyer No. 2 Farm at the same time. One-year Scotch pine seedlings were burned so severely that the bed was virtually ruined. Figure 1-11 illustrates the drastic stunting the burn produced in the seedlings. All of the seedlings shown in the photograph were 2 years of age in 1970 and were previously burned during the 1969 episode. The two seedlings on the left, although still living, have ceased growing whereas the one on the right, only slightly burned at the time, managed to achieve nearly normal growth in 1970. All of the beds were heavily damaged, although some seedlings recovered sufficiently in 1970 to be usable.

Acute burn of this type, although not as severe, was noticed in 1969 on several of the farms in this portion of the study area. In 1970, however, no burns of this magnitude were observed at any of these same farms. Nevertheless, since the growers had observed tree injury of this nature off and on since 1967, it is likely that the conditions will again appear on the farms in time.

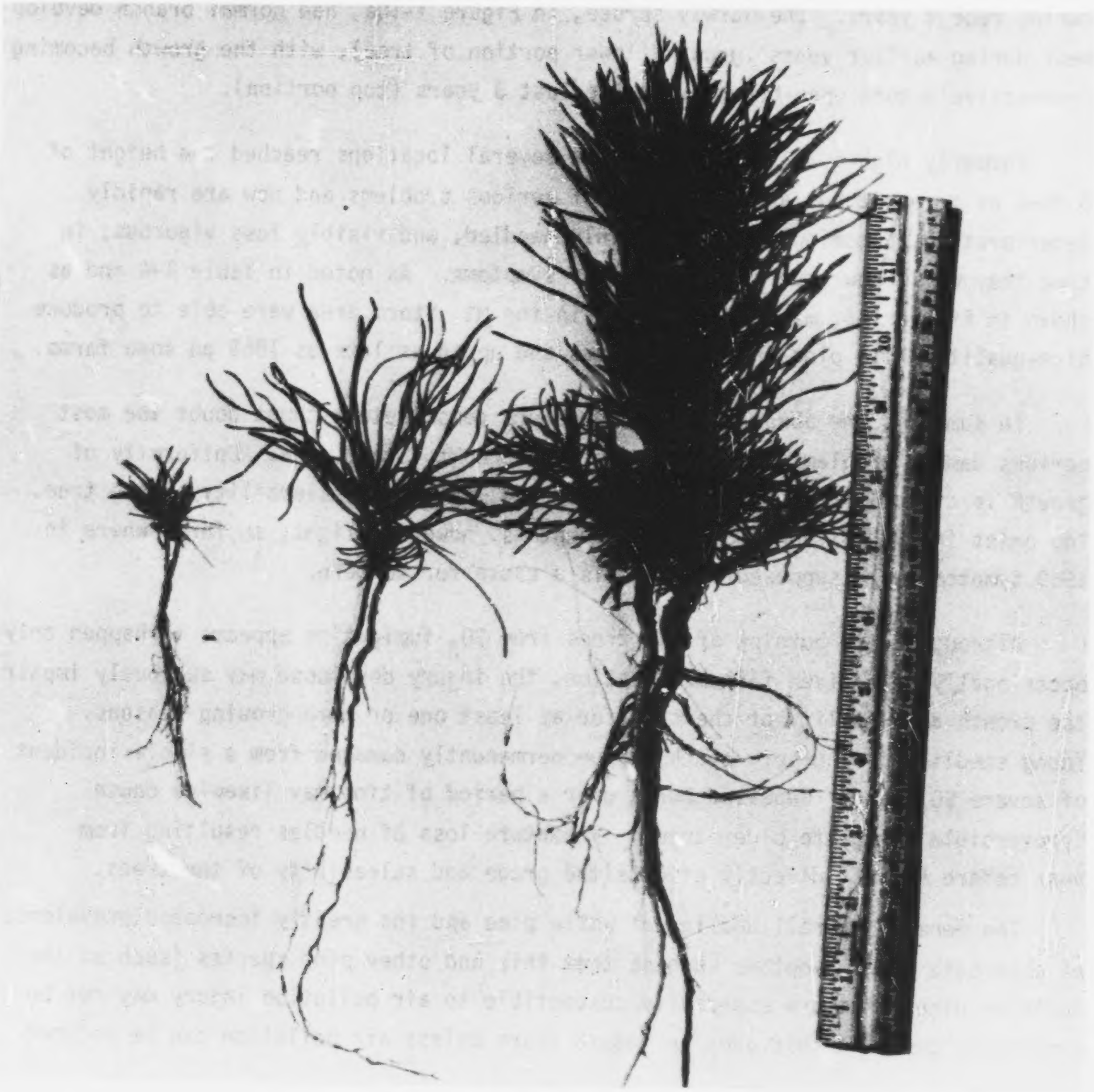


Figure 1-11. Stunted growth of Scotch pine seedling severely burned by SO_2 in 1969 compared with nearly normal-sized seedling of same age.

The onset of damage to the Christmas-tree farms in recent years is of interest. On several of the severely damaged farms the growers have contracted with the property owners for cutting rights which specified that the trees were to be removed from the field within a certain time period. Trees on the Stony River Farm were contracted for in 1964. Contracts for Steyer No. 4 and No. 5 Farms were negotiated as late as 1967 and 1968. The growers leasing these properties for cutting purposes are experienced and have indicated that they would not have entered into these contracts if the trees had been of other than satisfactory condition and quality at that time. The damaged trees themselves demonstrate that injury had occurred only during recent years. The Norway spruce, in Figure 1-10a, had normal branch development during earlier years' growth (lower portion of tree), with the growth becoming progressively more open-branched in the last 3 years (top portion).

Formerly high-quality white pine at several locations reached the height of 8 feet or more without any indication of serious problems and now are rapidly deteriorating, becoming yellowed, thinly needled, and visibly less vigorous; in time they will show true chlorotic dwarf symptoms. As noted in Table 1-4 and as shown in Figure 1-6, many of the farms in the Mt. Storm area were able to produce high-quality white pine in earlier years and up to as late as 1969 on some farms.

In summary, the abnormal growth problems constitute without doubt the most serious damage problems faced by growers in the Mt. Storm area. Uniformity of growth is directly related to the quality and, thus, the saleability of the tree. The onset in 1970 of abnormal growth symptoms, however slight, on farms where in 1969 symptoms were supposedly absent is a cause for concern.

Although acute burning of the trees from SO_2 fumigation appears to happen only occasionally at a given farm or location, the injury developed may seriously impair the growth and vitality of the tree for at least one or more growing seasons. Young seedlings or nursery stock may be permanently damaged from a single incident of severe SO_2 burn. Repeated burns over a period of time may likewise cause irreversible damage to older trees. Premature loss of needles resulting from burn before harvest directly affects the grade and saleability of the trees.

The general overall decline of white pine and the greatly increased prevalence of chlorotic dwarf symptoms suggest that this and other pine species (such as the Austrian pine) that are especially susceptible to air pollution injury may not be profitably grown in this area in future years unless air pollution can be reduced.

Transplantation Experiment

In April 1968, Dr. F. D. Custer transplanted Scotch pine with severe growth alteration symptoms—that is, needle-dwarfing, bud failure, early abscission, and retarded growth—from the Stony River Farm to the Custer Home Farm where such symptoms had not occurred. Trees lacking these symptoms were transplanted from the Custer Home Farm to the Stony Farm. His objectives were: (1) to see if damaged trees would improve when removed from a farm on which severe damage had occurred and to a farm where damage had not occurred, and (2) to see if healthy transplanted trees would show damage when transplanted from a damage-free farm to a farm where damage had occurred.

The following two growing seasons, 1969 and 1970, the severely injured trees, while still retaining remnants of the 1968 short-long needle syndrome, recovered and produced healthy, normal growth. Although needles produced immediately following transplant were uniformly short because of transplant shock, even this foliage presented a good appearance. Figures 1-12a and 1-12b show: (1) a damaged branch of a Scotch pine recently transplanted to the Custer Home Farm, and (2) the healthy 1970 growth on a tree transplanted in 1969 that at one time showed damage equally as severe. In contrast, trees that had been moved to Stony River Farm in 1969 began to show pronounced symptoms of abnormal growth by 1970. A branch from one of the Scotch pine moved to Stony River Farm is shown in Figure 1-13. Needles set before the tree was moved are normal, whereas later needles are damaged.

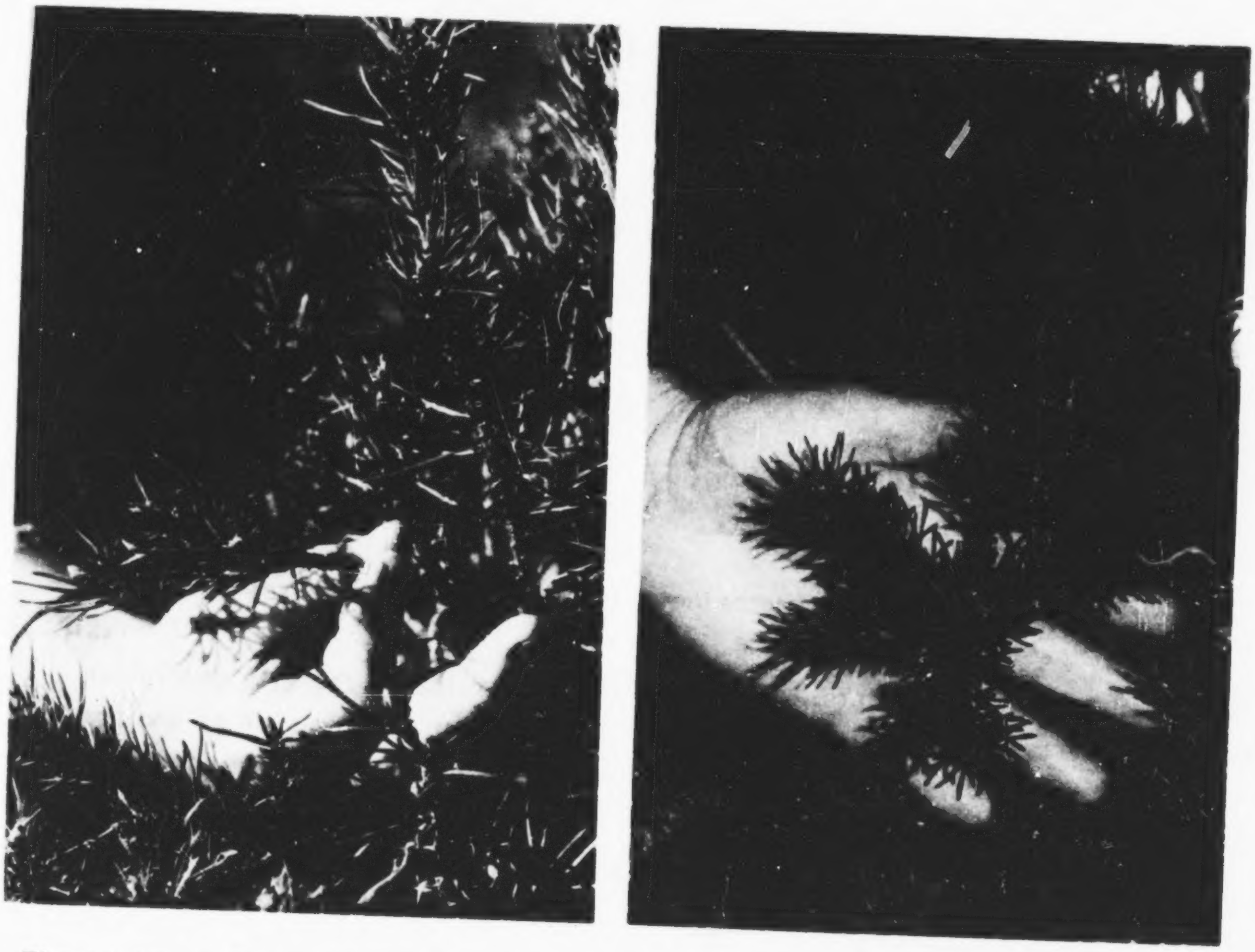


Figure 1-12. a. Typical severely damaged branches on Scotch pine recently transplanted from Stony River Farm to Custer Home Farm. b. Healthy current growth on trees transplanted in 1969 that recovered from previous damage.

The Custer Home Farm is more remote from any of the major sources of pollution (Section V) than the Stony River Farm. The improvement in trees transplanted to the Custer Home Farm appeared to be the result of lower levels of air pollution.

It has been suggested, however, that insect infestations, if responsible for the damage, might also be lower at Custer Home Farm, which would account for the

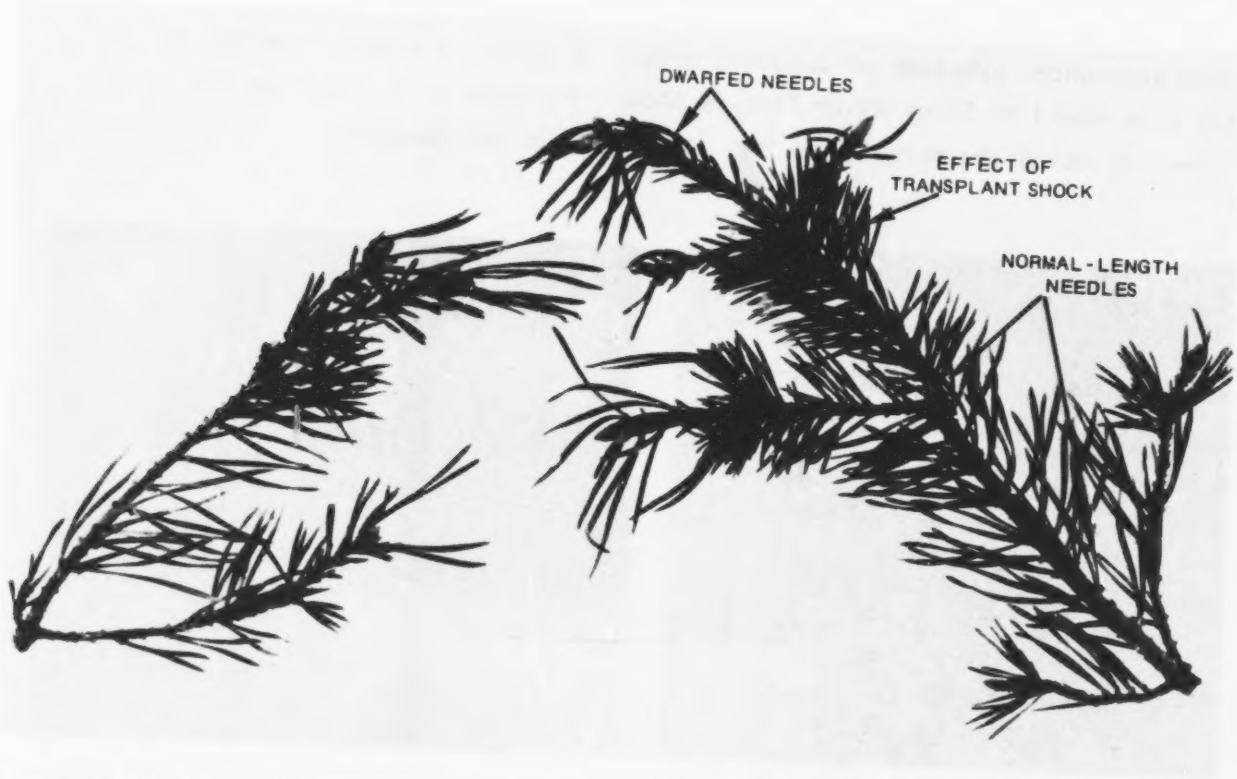


Figure 1-13. Abnormal growth on branches from formerly healthy Scotch pine transplanted to Stony River Farm.

improvement of the transplants. A survey, however, of insect and mite population at the two farms showed little or no difference.[31] Other factors such as the possibility of different soil conditions and exposure at the two farms were not considered.

Although the results can be interpreted to indicate that air pollution is the cause of growth aberrations on severely damaged trees at Stony River Farm, transplantation experiments designed to minimize influence of the variables would be required to prove the validity of this interpretation.

Entomological Studies

A survey was made of the farms listed in Table 1-4 for the purpose of determining whether insects or other small organisms might be involved in causing the damage. Dr. R. F. Anderson, Forest Entomologist, Duke University, Durham, North Carolina, examined trees in the field on several occasions in November 1969 and June through August 1970.

Samples collected during the field surveys and at other times by the growers were returned to his laboratory for microscopic examination. Detailed results of the entomological study are contained in a report prepared as a supplement to this technical report.[31]

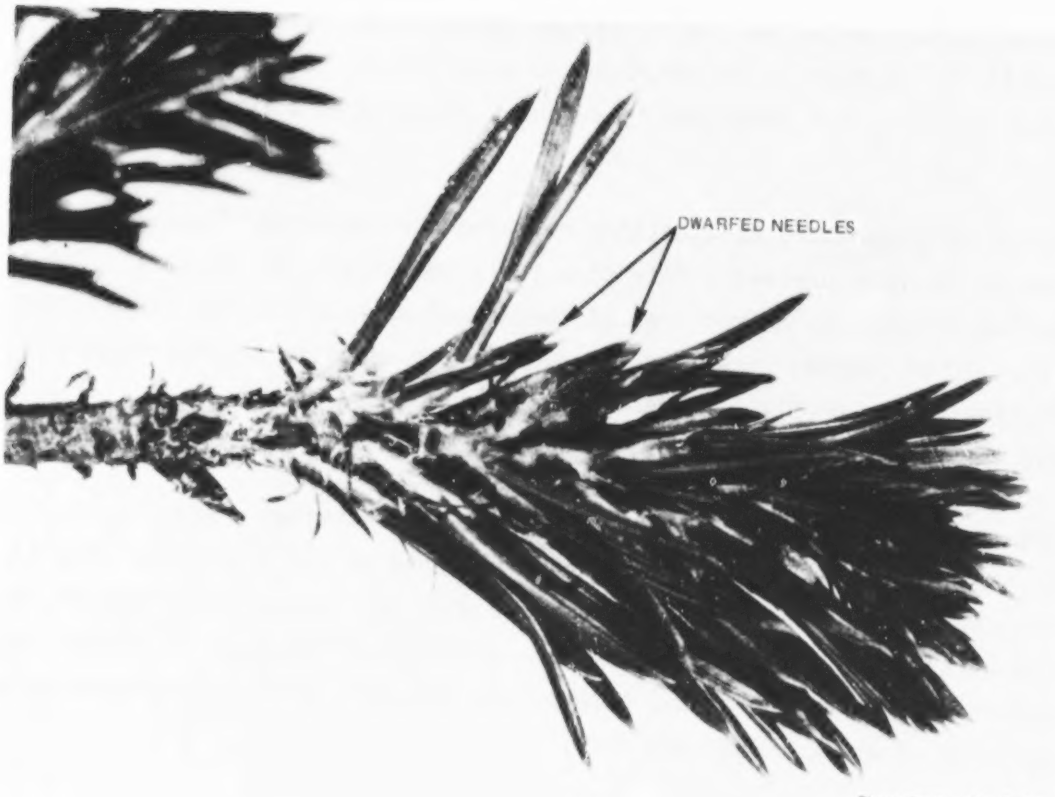
Field and laboratory examinations revealed that numerous insects and mites had been present or were presently infesting the trees to various degrees. The tree growers had already recognized some of the insect species and had taken remedial measures. Other species were found in numbers too small to be significant in contributing to the problem. At no location were there enough insects of any kind to cause the kind and amount of injury observed.

The complexity of the symptoms on injured trees further argued against insects as the cause. The types of injury suffered by the trees have never before been associated with the insects found, even when the insects were present in large numbers. The fact that so many tree species are involved is another reason to question insects as the cause, because one kind of insect seldom infests species as diverse as pines, spruces, and firs.

Necrotic spotting at the needle bases beneath the fascicle sheaths on the pines was not thought to be the effect of insect infestation either. Dr. F. A. Wood has suggested that feeding by eriophyid mites (Setoptus sp.) found infesting the trees was the cause of the basal spots and, in turn, the needle-dwarfing.[32]

Based on his observations and microscopic examination of injured needles, Dr. Anderson has suggested that the basal necrotic spotting of needles may not be caused by an organism, but instead may be the result of "acid burn." The ambiguous presence of flyash particles deposited on emerging needles around scales of the opening buds and needle sheaths on trees in severely affected areas is of interest. Acid or alkali leached from the particles is considered as a possible source of a protoplasmic poison. Also under consideration are acid aerosols emitted by the power plant and sulfur gases absorbed in dew or rainfall. Studies have shown that some of the SO_2 in power plant effluents may be oxidized to SO_3 by accompanying particulate matter or flyash, which react with moisture to form acid aerosols.[33, 34]

Work is continuing at the present time to establish possible mechanisms involved in any air-pollution-induced growth abnormalities. Preliminary investigation by Dr. C. C. Gordon, University of Montana, has shown that needle dwarfing can be induced in the lab by the topical application of weak acid to young, elongating needles as shown in Figure 1-14.



Photo, Courtesy Don Dodge

Figure 1-14. Laboratory-induced dwarfing of needles.

Histological Studies

For histological studies, injured and intact needles were collected from several plantations, processed microtechnically, and examined microscopically by Dr. I. Hindawi and Dr. C. C. Gordon, plant pathologists from APCO and the University of Montana, respectively.

The samples prepared by the APCO laboratory were hand-sectioned in order to obtain specimens without the distortion induced by killing, dehydrating, or freezing the tissue. Sections were taken at three points on damaged needles: the brown tip; the transition zone between the tip and banded areas; and from the banded area itself. A drawing of a pine leaf cross section is provided in Figure 1-15 to assist in identifying leaf parts referred to in the following discussion of histological data.

In needles having brown tips, collected in November 1969 from several farms (including Steyer No. 2) with trees showing severe burn symptoms, the endodermis was found to be partially or completely collapsed. In the mesophyll layer, chloroplasts were collapsed and disintegrated and both the cytoplasm and the nucleus had lost their identity. The xylem was intact, but the phloem was crushed and collapsed. The epithelial cells of the resin canals showed extreme expansion and swelling or had collapsed and broken down. In the transition zone the epithelial cells of the

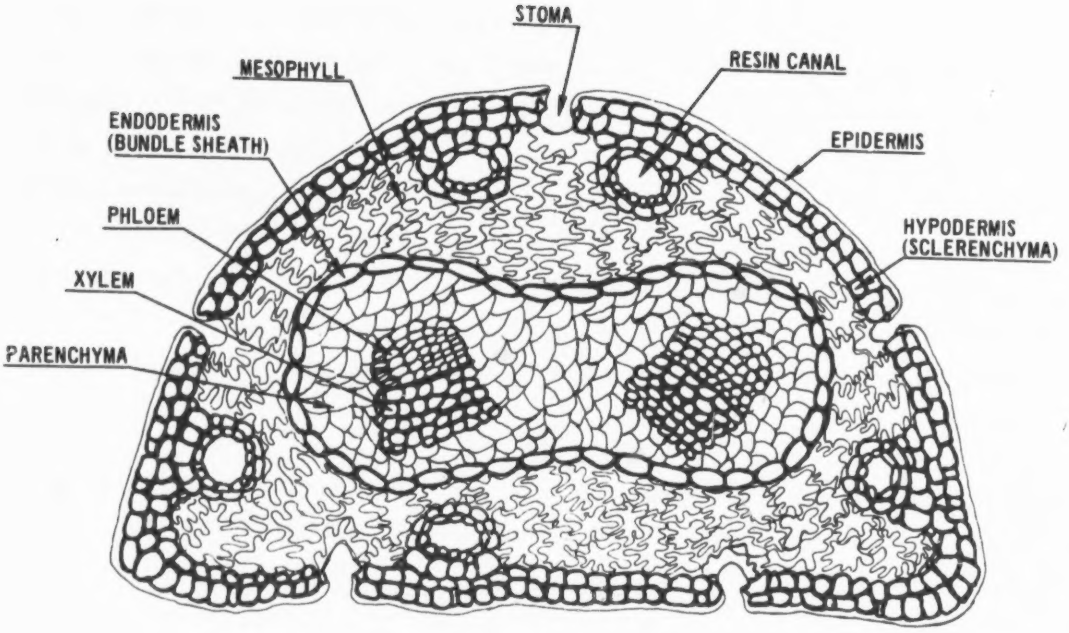


Figure 1-15. Cross section of pine leaf.

resin canals were expanded and swollen and many of them were in various stages of disintegration. Some of the phloem cells had become swollen.

In banded areas, the epithelial cells were enlarged and swollen as were a few phloem cells. The hypodermis contained yellow-brown pigmentation not found in healthy cells. Some chloroplasts in the mesophyll cells had broken down.

Healthy-appearing needles collected from the Weise-McDonald farm in 1969 were also sectioned and studied under the microscope. All of the tissues of these needles were intact, including the epithelial lining of the resin canals.

The epithelial cells of resin canals are apparently the cells most easily affected by sulfur dioxide or hydrogen fluoride. In general, cross sections from the tips of the injured areas showed resin canals completely occluded with swollen epithelial cells. In all of the affected zones, the mesophyll layer contained chloroplasts in various stages of disintegration.

The morphology of the plant damage described above clearly shows that the causative agent of tip burn observed on the tree farms was of a chemical nature. This is borne out by the extensive changes that occurred throughout the plant tissues. These pathologic changes could not have been caused by insect or fungus infestation, winter damage, or wind exposure.

Histological studies made by Dr. Gordon confirm APCO's findings that injury on needle samples collected from farms where severe tip burn manifested itself in November 1969 (previously described) is of a chemical nature.

In addition to many of the symptoms already described, Dr. Gordon found hypertrophy of the parenchymal cells of the transition tissues, which is indicative of sulfur dioxide or hydrogen fluoride toxicity. He found, as well, that the horseshoe-shaped mesophyllic cells located directly beneath the stomata were destroyed, which, again, is symptomatic of toxicity of sulfur-containing gases and acids. Too, the disintegration of the chloroplasts and the hypertrophy of the epithelial cells of the resin canals can be attributed to sulfur dioxide, hydrogen fluoride, or hydrogen sulfide toxicity. Since the nuclei of the epithelial and mesophyllic cells were disintegrated, however, hydrogen fluoride toxicity can be ruled out.

Thus, these studies implicate sulfur dioxide as the major causative agent in the extensive needle burn observed on Scotch pine growing in field and nursery beds at the Steyer Farms.

Details of Dr. Gordon's studies and illustrative photomicrographs of sectioned injured and healthy needle tissue are contained in his report to APCO prepared on a supplement to this report.[35]

Chemical Studies

Sulfur dioxide entering the stomata of a leaf is thought to be oxidized in the leaf to form sulfuric acid, which reacts with organic bases. The resulting sulfates are apparently translocated and deposited in the leaf tissue. Large amounts of sulfate are found in leaves with chronic symptoms whereas only a small increase in sulfate content occurs in leaves with acute injury.[36]

Conifer needles were collected in the fall of 1969 from a number of farms in the area for analysis of total sulfur content. The analysis was made to determine the relative sulfur concentration in needles from different locations in the area and to correlate variations in concentration with proximity to known SO_2 sources.

Scotch pine trees were selected for analysis because they were being grown at the majority of the farms and generally retained both first- and second-year needles. Needle samples were sent to the Wisconsin Alumni Research Foundation Laboratory in Milwaukee, Wisconsin, for total sulfur analysis. The collection sites, year of needle emergence, and results of chemical analysis are listed in Table 1-5.

The sulfur concentration in the needles ranged from 500 to 3,750 ppm. Unpublished work[37] indicates that sulfur concentrations greater than 500 ppm generally indicate SO_2 contamination but that concentrations greater than 1,000 ppm definitely indicate SO_2contamination.

Table 1-5. TOTAL SULFUR ACCUMULATION IN SCOTCH PINE NEEDLES FROM SELECTED SITES

Site no.	Location[a]	Year of needle growth	Sulfur, ppm
1	Stony River Farm	1969	1,000
		1968	1,200
2	Steyer No. 1 Farm	1969	800
		1968	1,100
3	Steyer No. 5 Farm	1969	3,200
		1968	3,750
4	Steyer No. 2 Farm	1969	1,100
		1968	700
5	Weise-McDonald Farm	1969	500
		1968	600
6	4-H Club Farm (northeast boundary of study area)	1969	500
		1968	500
7	Custer Home Farm	1969	500 to 600
		1968	500 to 1,000
8	Taylor (Kempton) Farm	1969	900
		1968	600
9	Pulp mill vicinity (Westernport, Maryland)	1969	2,500
		1968	3,100

[a] Location of farms shown in Figure 1-7.

Samples from tree farms in the vicinity of the Mt. Storm Power Plant (Sites 1, 2, 3, 4, and 8) contained higher concentrations of sulfur than were found in samples from those farms farther away, in the northern portion of the area (Sites 5, 6, and 7). The sulfur content of needles collected near the pulp mill was significantly higher than it was in most of the needles from the other sites and was exceeded only at the Steyer No. 5 Farm. Analysis of needles from several sites showed that more sulfur was present in current-year needles (1969) than in needles from the previous year (1968), which perhaps indicates greater SO_2 contamination during the 1969 growing season at these location.

Vegetation Experiments

In addition to the field inspection in 1970, vegetation experiments were conducted at three of the farms. These experiments are described in this section but conclusive results are not yet available.

The first of these experiments was designed to show the effect on conifers of proximity to the power plant. At the Stony River Farm, fifty 8-year-old, 3- to 4-foot Scotch pine trees showing severe damage were transplanted into baskets. Half of these were kept on the farm; the other half were taken to the Weise-MacDonald Farm, where damage to Scotch pine was minimal. Half of the basketed trees at both sites were sprayed with an insecticide.

In a similar manner, fifty healthy Scotch pine were dug at the Weise-MacDonald plantation and basketed. Half were taken to the Stony River Farm, and set beside those trees that were dug out and kept on the farm. Again, half of each group was sprayed with the same insecticide used on the damaged trees. Improvement in growth of those trees taken from the Stony River Farm and grown at the Weise-MacDonald plantation would demonstrate a proximity effect. Similarly, a decline in vitality of those trees removed from the latter plantation and grown near the power plant on the Stony River Farm would likewise show the effect.

The second experiment was designed to investigate the genetic susceptibility of individual trees as well as the possibility that viral infections were the cause of the difficulties. One hundred scions (live cuttings) from Scotch pine exhibiting abnormal growth habits on the Stony River Farm were taken. Half were grafted to healthy stock on the farm and the other half grafted to healthy trees on the Weise-MacDonald plantation.

A third experiment was designed to determine if vegetation growth improves in clean air. Two growth chambers (5 by 7 by 6 feet) were built on the Stony River Farm. One chamber was equipped with an air-filtration system to remove gaseous and, to some extent, particulate pollutants, while the other chamber was ventilated with unfiltered ambient air. In both chambers several special plant varieties were grown: tobacco, pinto bean, petunia, gladiolus, Scotch pine (one in natural soil and one in a pot), and assorted small pine trees (in pots). An identical experiment was carried out at the Steyer No. 2 Farm. Plants were exposed in this manner for a 10-week period beginning in June 1970.

Results of these experiments are not available at this time. The basketed trees showed transplant shock, which will delay the appearance of any definite proximity effect until next growing season. Similarly, the grafts will not exhibit effects until the 1972 growing season. The growth-chamber experiments are showing results, but the effect of clean air on Scotch pine growth may have been partially obscured by the stimulating effect of higher temperatures in the chamber and generally low ambient sulfur dioxide levels present during the test.

Impact of Tree Damage

Christmas-tree farms are characteristically high-volume, low-margin operations. The saleability of trees is ultimately decided by individuals on the basis of subjective evaluation of shape, foliage, and color. Injuries of the type observed in the Mt. Storm area render a large percentage of the trees unmarketable or bring reduced prices. As a result, the owners of the more severely damaged Christmas-tree farms are in danger of going out of business. There have been no plantings on the farms on the Mt. Storm side of Backbone Mountain in the last 2 years because of the uncertainty of bringing future harvests to full maturity without sustaining damage. Stands of trees that over a period of years have been planted, fertilized, and sheared will not be harvested.

The field survey has indicated that a similar trend may occur in time at the farms more distant from Mt. Storm. It is likely that, as time passes, a larger area will be incapable of supporting a viable Christmas-tree farming operation.

The further implications of the tree injuries are less tangible. The damage to the sensitive pines, however, is indicative of potential damage to other trees and vegetation throughout the region. The worsening conditions observed over the past several years can be expected to continue, with observable effects becoming more numerous.

REFORESTATION AREAS

The Maryland State Division of Forestry inspected a number of the reforestation areas in Garrett County in the fall of 1970 and found damage symptoms similar to those on the Christmas-tree farms.[38] The trees planted for reforestation differ from trees being grown for ornamental or Christmas-tree production only in that they are unsheared and are allowed to grow to maturity. Several of the state-operated forest areas are located near the Christmas-tree farms where air-pollution-related damage has occurred. One prime Eastern white pine stand on state forest land near Steyer No. 5 Farm has been set aside by the state agency as a major seed-producing orchard for its program.

Chlorosis, or yellowing of needles, and early abscission appeared to be affecting white pine on forest plantations throughout Garrett County. "Twisted" or severely kinked needles were also frequently observed on the white pine. As a consequence of this needle damage, few of the trees are holding more than 1-year needles.

Although no estimate of the degree of damage or the number of trees affected was made, damage was most noticeable on reforestation areas in western and southern Garrett County. Scotch pine and Virginia pine in these areas showed long-short needle syndrome, bud failure, and early abscission, whereas Scotch pines located northeast of Deep Creek Lake were healthy and holding 2- and 3-year needles.

Although unsightly foliage does not affect the value of trees for pulp purposes, as it does those destined for the Christmas-tree market, the state agency is concerned that the damage may, in time, cause the trees to become less vigorous, affecting growth rate or weakening them so that they become more susceptible to insect or desease injury.

Linzon[39] in a recent study of economic effects of sulfur dioxide on forest growth found a gradual decline in the growth of white pine in areas close to sources of pollutant. Atmospheric SO_2 at relatively low long-term concentrations ($>$0.01 ppm to 0.045 ppm) caused perennial foliage injuries to white pine and upset physiological processes. Reduced chloroplasts, the pigmented cells necessary for photosynthesis, resulted in reduced annual growth and increased tree mortality.

V. DESCRIPTION OF SOURCES

Potential sources of air pollution in the survey area include several burning coal-refuse banks in Garrett and Grant Counties, a charcoal plant in Garrett County, a Kraft pulp mill in Allegany County, and, as previously mentioned, the Mt. Storm Power Station in Grant County. Location of these sources in relation to the tree farms is shown in Figure 1-16.

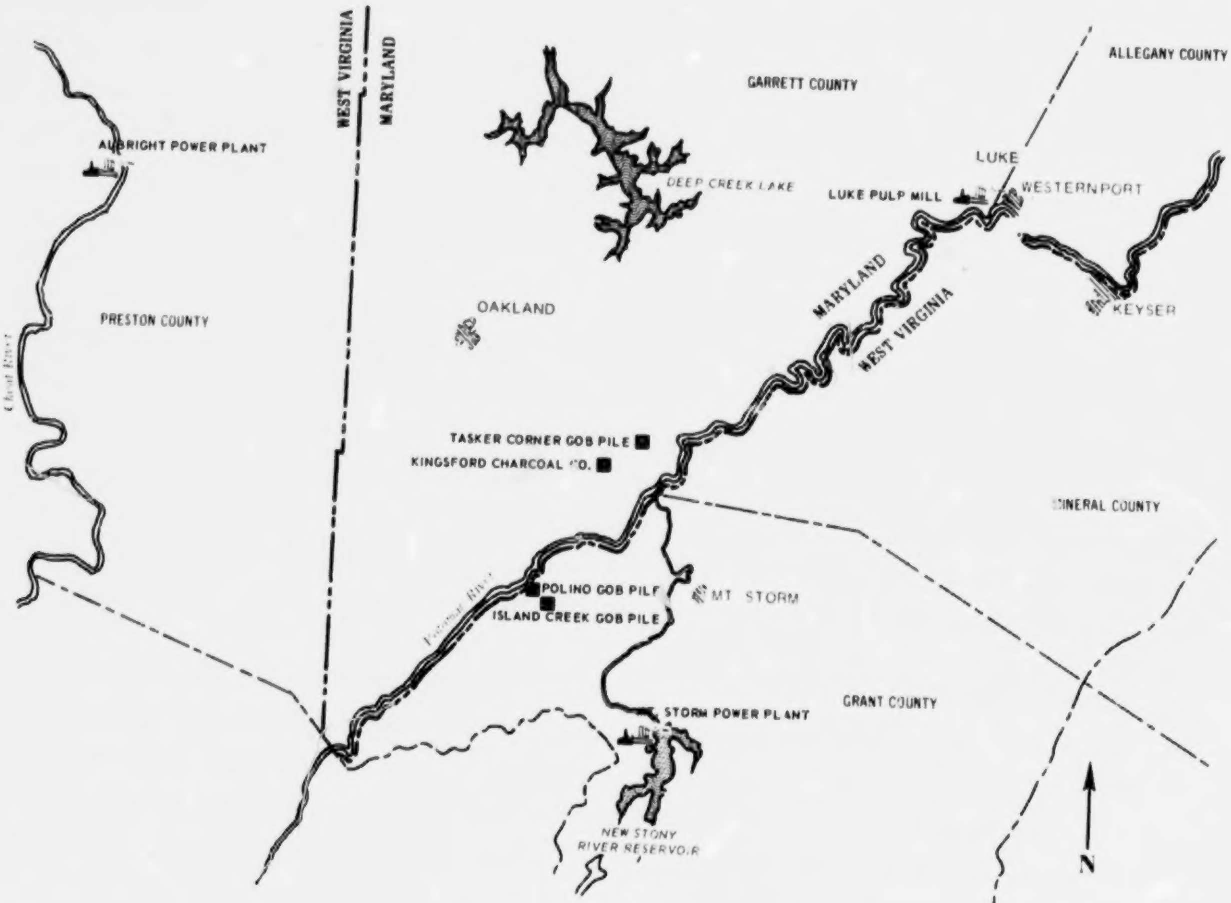

WEST VIRGINIA
MARYLAND
GARRETT COUNTY
ALLEGANY COUNTY
ALBRIGHT POWER PLANT
DEEP CREEK LAKE
LUKE
LUKE PULP MILL
WESTERNPORT
PRESTON COUNTY
OAKLAND
MARYLAND
WEST VIRGINIA
KEYSER
Cheat River
TASKER CORNER GOB PILE
KINGSFORD CHARCOAL CO.
MINERAL COUNTY
Potomac River
POLINO GOB PILE
ISLAND CREEK GOB PILE
MT. STORM
MT. STORM POWER PLANT
GRANT COUNTY
NEW STONY RIVER RESERVOIR
N

Figure 1-16. Location of potential air pollution sources in study area.

Large coal-burning power plants that exist outside the area may, under certain meteorological conditions, contribute measurable levels of pollution in the vicinity of the farms. One of these, the Albright Power Station, is situated in Preston County, West Virginia, within 8 miles of the Maryland-Garrett County line, whereas the others are located farther to the northwest, in the Morgantown and Pittsburgh vicinity (Figure 1-4). Located near the Albright plant is a metallurgical plant, a potential source of fluorides.

Descriptions of the sources and their relative contributions of sulfur oxides and other pollutants follow.

MT. STORM POWER PLANT

The Mt. Storm Power Station, designed as a mine-mouth power plant, is part of the Virginia Electric and Power Company (VEPCO) system. The installed generating capacity of the plant is 1,159,074 kilowatts, which constitutes about 29 percent of the company's total generating capacity. The plant is located next to the New Stony River Reservoir about 5 miles south of Mt. Storm, West Virginia.

The facility includes two 570,240-kilowatt, coal-fired, steam electric-power generating units. The first unit went into commercial operation in the fall of 1965; the second began in the summer of 1966. The plant also includes 18,594 kilowatts of oil-fired turbogenerator capacity. The company has received approval from the Public Service Commission of West Virginia to install an additional 555,000-kilowatt unit for service by March 1973. Provisions for this unit were included in the original plant design.

The existing boilers are of the dry-bottom type and are fired with pulverized coal. Both of the units are equipped with electrostatic precipitators designed for 96 percent efficiency at full load, and each unit is connected to a 350-foot stack. Data on the steam electric-power-generating units, the electrostatic precipitators, and the stacks are given in Table B-1 (Appendix B). During 1968 the plant generated about 69 percent of its full-load capacity. Tables B-2 and B-3 (Appendix B) show monthly power generation and coal consumption for the years 1967 through 1970.

The electrostatic precipitator fly-ash-removal systems at the Mt. Storm plant have not performed according to expectations and, at times, the system is unable to remove all the fly ash collected. The company is correcting this condition by replacing the existing fly-ash-handling equipment. Installation of the new system was scheduled for completion by May 1970. Because of the poor performance of the fly-ash-handling systems, at times all of the fly ash from the steam generators can be discharged to the stacks. When that occurs, particulate emissions are estimated to be 30 tons per hour per unit at full load, or a total of 60 tons per hour. When the electrostatic precipitators perform at 96 percent efficiency, total particulate emissions are estimated to be reduced from 60 to 2.4 tons per hour.

Total plant sulfur oxides emissions for 1968 are estimated at 120,000 tons, or an average of 13.6 tons per hour. At full load, sulfur oxides emissions from the burning of coal with an average sulfur content of 2.4 percent are estimated at 19.8 tons per hour. Of the sulfur oxides emitted, 1 to 2 percent is as sulfur trioxide and the remainder as sulfur dioxide. Some West Virginia coal contains up to

0.02 percent fluoride, which is released to the atmosphere during combustion. This amount of fluoride in the coal charged to the Mt. Storm plant boilers at full load would result in an emission rate of about 170 pounds per hour.

The plant site is more than 3000 feet above mean sea level and is in a well-exposed area of the Allegheny Plateau. The site experiences higher wind speeds, greater turbulence, and less frequent inversions than do valley locations in the area. Air contaminant emissions are discharged directly into the high-level wind pattern. These features facilitate pollution dispersion and reduce long-term, ground-level concentrations, particularly in the plant vicinity. They do not, however, affect plume behavior conducive to the infrequent but high short-term levels that are sometimes experienced many miles from the plant under certain meteorological conditions.

WESTVACO PULP MILL

The Westvaco pulp mill is located along the Potomac River in Luke, Maryland. A complete description of the mill and an estimate of emissions are given in Part Two of this report. For the purposes of this section, only total plant emissions of SO_2 and particulates are considered.

The major sources of particulate and sulfur oxides emissions are the plant boilers and two recovery furnaces. Annual particulate emissions are estimated at 3,700 tons per year from the boilers and 2,300 tons per year from the recovery furnaces. Sulfur oxides emissions are estimated to be 21,000 tons per year from the boilers and less than 300 tons per year from the recovery furnaces. The pulp mill along with the towns of Westernport, Luke, and Piedmont, is situated in a box-like canyon that empties to the northeast, down the Potomac River drainage. The mountains to the west, south, and east, which enclose the towns and pulp mill, rise 1000 to 1,500 feet above the 1,020-foot elevation of the pulp mill site. Air contaminants emitted by the plant are inhibited by the topography from dispersing widely over the study area.

OTHER SOURCES IN STUDY AREA

Burning Coal Refuse Banks

Coal refuse banks in the area were inspected in the fall of 1969 to determine the extent of burning activity and to estimate the sulfur oxides emitted. Five burning "gob" piles were surveyed, three of which—Polino, Island Creek, and Taskers Corner—are located near enough to Steyer No. 1 and Steyer No. 5 tree farms to be potential sources of air pollution affecting the farms.

Although some burning activity was noted at all of the piles, total sulfur oxides emissions are estimated to be less than 100 tons per year. In comparison with emissions from other sources, burning coal refuse does not contribute significantly to sulfur oxides levels in the area. The fact that SO_2 was barely detectable in the immediate vicinity of these piles further indicates that they do not appreciably contribute to the ambient levels.

Kingsford Charcoal Plant

The Kingsford plant produces charcoal by charring wood in kiln-like ovens. Although copious quantities of dense white smoke are given off as the wood is charred, because of the low sulfur content of wood, sulfur oxides emissions are negligible.

SOURCES OUTSIDE STUDY AREA

Albright Power Plant

The Albright Power Plant is owned jointly by the Potomac Edison Company and Monongahela Power Company. The Monongahela Power Company's installed generating capacity is 209,250 kilowatts, and the Potomac Edison Company's capacity is 69,000 kilowatts. This plant, which is located northwest of the study area near Kingwood, West Virginia, began full-scale operation in 1954. The plant includes three steam electric-power generating units. Units 1 and 2 are equipped with mechanical dust collectors rated at 84 percent efficiency; both units have separate 160-foot-high stacks. Unit 3 is equipped with a combination mechanical collector and electrostatic precipitator system rated at 97 percent efficiency; it is connected to a 225-foot-high stack. During 1968, the Albright Plant generated about 88 percent of its full-load capacity. Peak hourly demand on Unit 1 was 82,900 kilowatts as compared with a 69,000-kilowatt capacity rating. Peak hourly demand on Units 2 and 3 was 225,000 kilowatts as compared with a total 209,250-kilowatt capacity rating. Particulate emissions at full load are estimated at 2.1 tons per hour when the dust-collection equipment is operating at rated efficiency. Annual emissions are estimated at 16,000 tons.

Sulfur oxides emissions are estimated at 7.2 tons per hour under full-load conditions and when coal with an average sulfur content of 2.75 percent is burned; annual emissions are estimated at 55,000 tons. Assuming a fluoride content in the coal of 0.02 percent, approximately 55 pounds fluoride per hour would be emitted at full load.

The plant is located in the Cheat River bottom at an elevation of 1,200 feet above MSL. Surrounding valley ridges rise several hundred feet above the plant stacks. Air contaminants emitted from the plant are generally entrained in the low-level wind patterns and dispersed. Although nearby ridges are subjected to high concentrations of pollutants, the plant is not expected to appreciably influence pollutant levels area-wide.

Manganese Corporation Plant

A metallurgical plant operated by the Manganese Corporation is located near Kingwood, West Virginia (in the vicinity of the Albright Power Plant). Emissions from the 14 electric-arc furnaces at this plant include gaseous and particulate fluorides. A venturi scrubber operating with a pressure drop of 20 inches of water has been installed at the plant and reportedly reduces fluoride emissions to a minimum.

Other Coal-Fired Power Plants Outside Study Area

In addition to the Albright Power Station, several other power plants are located outside the study area and to the northwest, but within 50 miles of the tree farms. Three power plants, because of fuel quantities burned and prevailing wind direction, are possible contributors to background levels of sulfur dioxide in the Mt. Storm area. These plants are:

1. Fort Martin Power Plant - a 1,140-megawatt station owned by Monongahela Power Company and located north of Morgantown, West Virginia, on the Monongahela River.
2. Rivesville Power Plant - a 175-megawatt plant owned by Monongahela Power Company and located near Fairmount, West Virginia.
3. Hatfield Ferry Power Plant - a 1,016-megawatt station owned by West Penn Power Company and located near Masontown, Pennsylvania.

A theoretical analysis of the relative sulfur dioxide contributions of these plants, as well as of the power stations at Albright and Mt. Storm, to long-term levels in the area appears in Section VII. For the purpose of this analysis, emission rates were calculated using annual fuel consumption data[40] and assuming a uniform fuel sulfur content of 2 percent. Future emission quantities were derived for each plant based on projected generating capacity and present fuel quanity burned per megawatt output.

In summary, coal-burning power-generation facilities were responsible for more than 96 percent of the particulate emissions and nearly all of the sulfur oxides emissions in the study area. There are two such units in the area—the Mt. Storm Power Station and the power boilers associated with the Westvaco Pulp and Paper Mill. Emissions from sources in the study area and from the Albright Power Station are summarized in Table 1-6. Only the pollutants of primary interest—particulates and sulfur oxides—are listed.

The Mt. Storm Power Station is the major source of both sulfur oxides and particulates in the study area. Its higher elevation relative to the surrounding

TABLE 1-6. ESTIMATED SOURCE EMISSIONS
(tons/yr)

Source	Particulates	Sulfur oxides
Mt. Storm Power Station	59,500	120,000
Westvaco	6,000	21,000
Kingsford Charcoal Plant	Unknown	Negligible
Coal refuse banks	Negligible	<100
Albright Power Station	16,000	55,000

mountainous area is conducive to a more area-wide distribution of contaminants than other sources, and occasional high concentrations from fumigation on high plateaus and ridges.

The Westvaco Mill and the Albright Power Station also emit significant quantities of air contaminants. The deep valley locations of these plants, however, undoubtedly inhibit the distribution of pollution over a large area. While emissions from these plants create localized air pollution problems of a considerably greater magnitude than any found in the vicinity of the tree farms, the potential for area-wide contamination from these sources appears slight.

VI. AIR QUALITY MEASUREMENTS

In order to determine the presence and concentrations of air pollutants in the study area, both static and continuous air measurements were made during a 4-month period, June through September 1970. Air monitoring stations were located at three farms: Stony River Farm, the Steyer No. 2 Farm, and the Weise-McDonald Farm. Sulfur dioxide, oxidants, and nitrogen oxides were measured continuously at these locations and, on alternate days, 24-hour suspended particulate and fluoride samples were collected.

The static sampling network consisted of 76 stations. Dustfall containers for measuring settleable dusts were placed at 24 sites, sodium formate plates for estimating fluoride levels were placed at 60 sites, and lead peroxide plates for determining sulfation rates were placed at every station. The static sampling devices were exposed for monthly intervals and returned to the laboratory for chemical analysis. The sampling locations were widely distributed over the area in an attempt to characterize the spatial distribution of these substances. The static sampling locations are listed in Table A-1 (Appendix A) and shown in Figure 1-17.

In addition to air quality measurements, observations of surface wind direction and speed were made at four sites in the area during the survey to augment National Weather Service observations at the Pittsburgh Airport. The meteorological measurements provided information necessary for proper interpretation of air sampling data. The continuous air monitoring and meteorological stations are shown in Figure 1-18.

SULFUR DIOXIDE

Sulfur dioxide (SO_2) is a gaseous pollutant formed principally by the combustion of sulfur-bearing fossil fuels.

Continuous Measurements

Coulometric analyzers were used to measure SO_2 concentrations at the three farm sites. The analyzers were dynamically calibrated during the study period, and electronic and static checks were performed on each instrument daily.

Results, expressed as hourly averages (Table 1-7), generally indicate low long-term SO_2 concentrations during the measurement period. An average concentration of only 0.01 ppm was observed at the Stony River Farm, while at the other two locations,

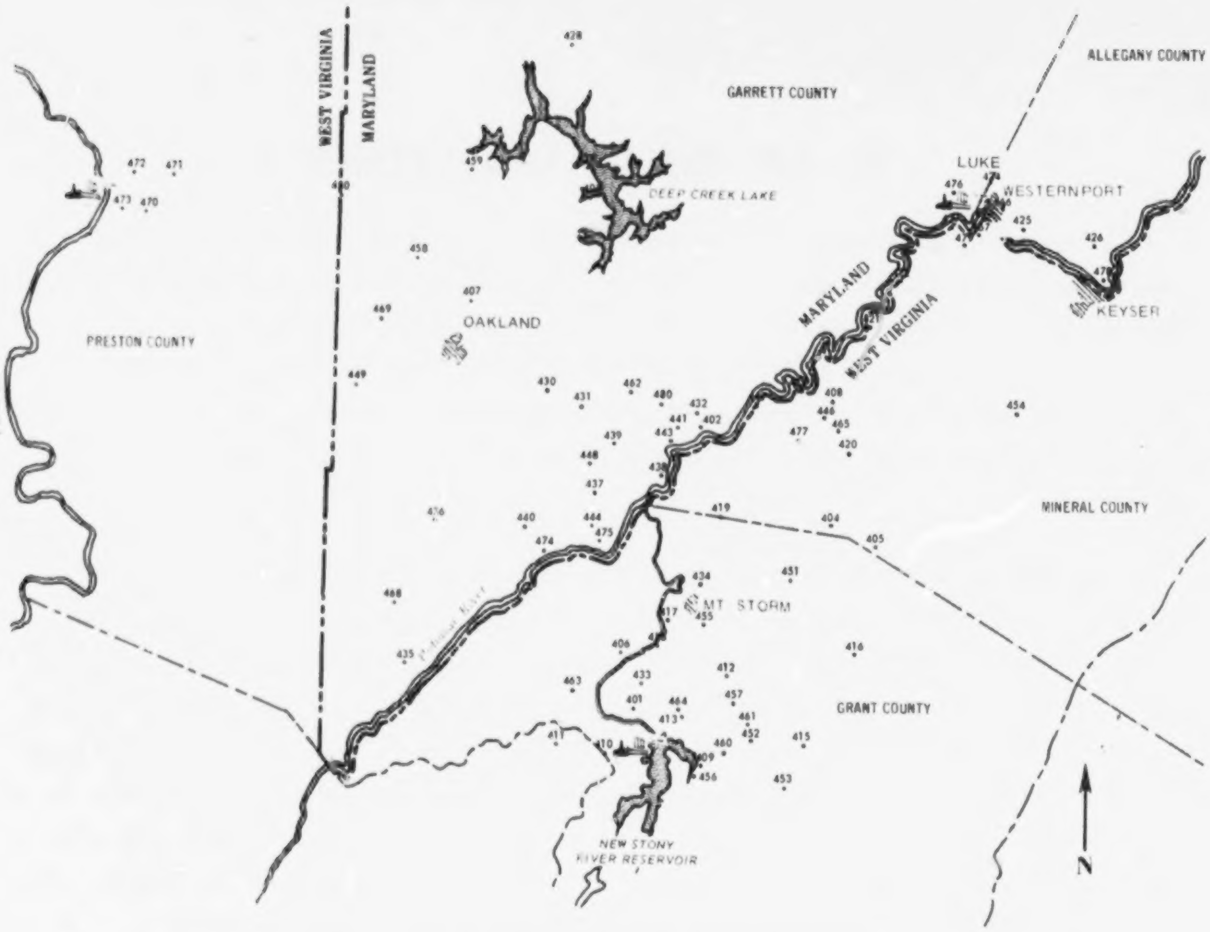

WEST VIRGINIA
MARYLAND
GARRETT COUNTY
ALLEGANY COUNTY
DEEP CREEK LAKE
LUKE
WESTERNPORT
KEYSER
OAKLAND
PRESTON COUNTY
MARYLAND
WEST VIRGINIA
MINERAL COUNTY
MT STORM
GRANT COUNTY
NEW STONY RIVER RESERVOIR
N

Figure 1-17. Location of static sampling stations.

concentrations were below this level. The maximum hourly value recorded during the 4-month period was 0.36 ppm at the Stony River Farm, 0.11 ppm at the Steyer No. 2 Farm, and 0.10 ppm at the Weise-McDonald Farm.

Air Quality Criteria for Sulfur Oxides[41] notes that adverse health effects can occur when SO_2 levels exceed 0.11 ppm for 3 or 4 days, and chronic plant injury and excessive leaf drop are to be expected at an annual mean of 0.03 ppm. Values presented in Table 1-7 show that measured concentrations at the three sites were lower than these levels during the study period.

Table 1-7. SUMMARY OF HOURLY SULFUR DIOXIDE MEASUREMENTS, MAY 28 THROUGH SEPTEMBER 28, 1970

Station	No. of observations	Concentration, ppm		Percent observations equal to or exceeding	
		Maximum value	Average value	0.02 ppm	0.10 ppm
1 - Stony River	2,060	0.36	0.01	10.6	1.2
2 - Steyer No. 2	2,572	0.11	<0.01	10.3	<0.1
3 - Weise-McDonald	2,479	0.10	<0.01	9.0	<0.1

The Environmental Protection Agency has proposed primary and secondary national air quality standards for several pollutants, including SO_2, particulates, and oxidants.[42] Primary standards are based on health effects, and secondary standards are based on effects on vegetation, materials, animals, visibility, personal comfort, and well-being.

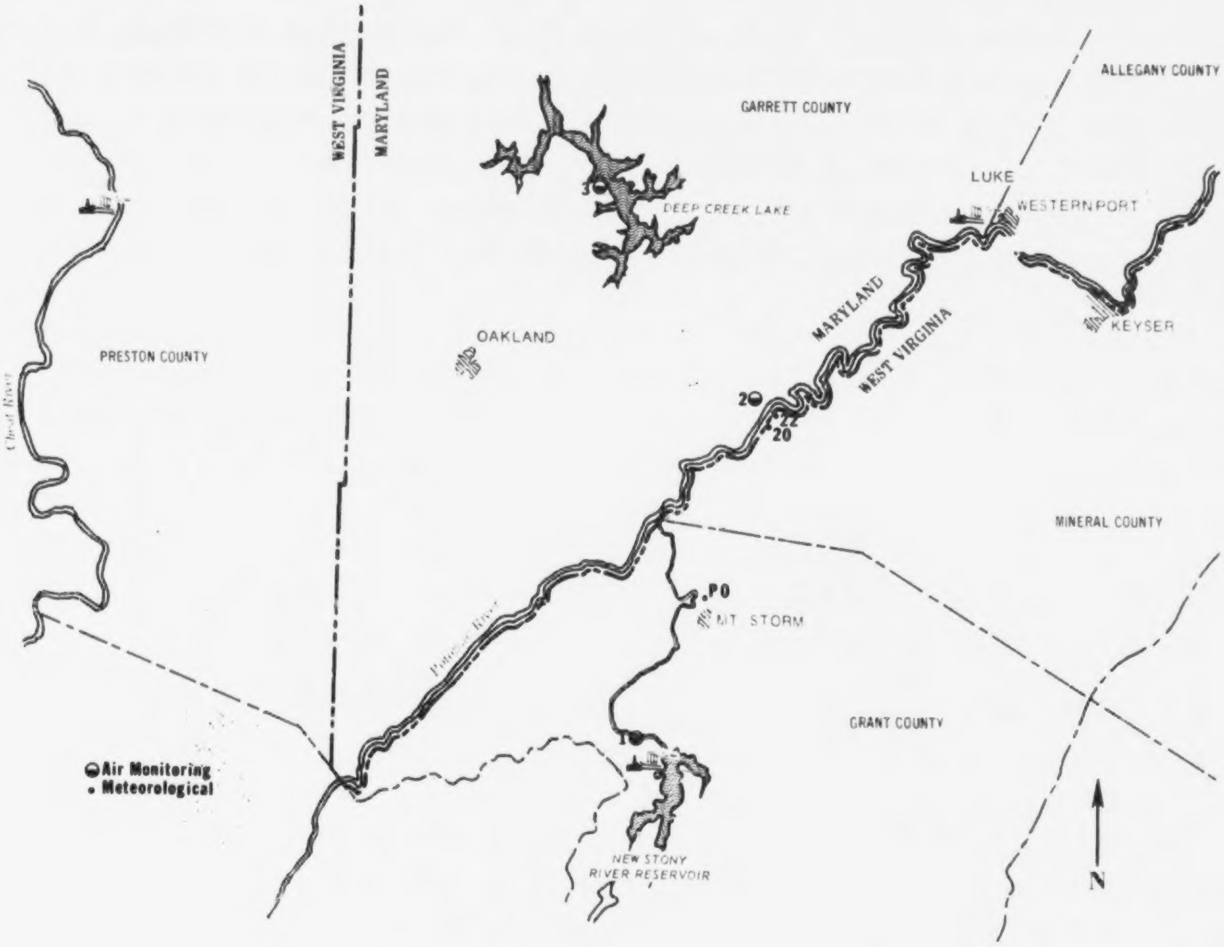

WEST VIRGINIA
MARYLAND
GARRETT COUNTY
ALLEGANY COUNTY
3
DEEP CREEK LAKE
LUKE
WESTERNPORT
KEYSER
OAKLAND
PRESTON COUNTY
Cheat River
MARYLAND
WEST VIRGINIA
2
22
20
MINERAL COUNTY
PO
MT. STORM
Potomac River
GRANT COUNTY
1
Air Monitoring
Meteorological
NEW STONY
RIVER RESERVOIR
N

Figure 1-18. Location of continuous air monitoring and wind observation stations.

Standards proposed for SO_2, expressed in $\mu g/m^3$, are:

	Maximum 24-hour concentration	Annual mean
Primary	365 (0.14 ppm)	80 (0.03 ppm)
Secondary	260 (0.10 ppm)	60 (0.023 ppm)

Average concentrations measured at the three sites were less than the proposed secondary standard for annual mean concentration. Only at Stony River Farm did the 24-hour maximum value (0.08 ppm) approach the secondary 24-hour standard.

Particularly important, however, were the several incidents of very high short-term SO_2 concentrations that did occur at the Stony River Farm. On September 12, a peak 15-minute concentration in excess of 0.50 (off analyzer scale) was recorded, and the peak concentration was extrapolated to be in the range of 0.8 to 1.0 ppm. Prior to reaching this peak, SO_2 levels had shown a gradual buildup and had averaged 0.25 ppm for over an hour. The chart graph taken during this period at the Stony River Farm Station is shown in Figure 1-19. The repeated occurrences of high SO_2 concentrations throughout the day indicate that the episode was probably the result of limited vertical mixing conditions. At such times the dispersion of the pollutants is restricted by an elevated, presistent inversion. Whenever the station is downwind of the source, high concentrations occur. Correlations of this and other instances of high SO_2 pollution with wind direction are contained in Section V.

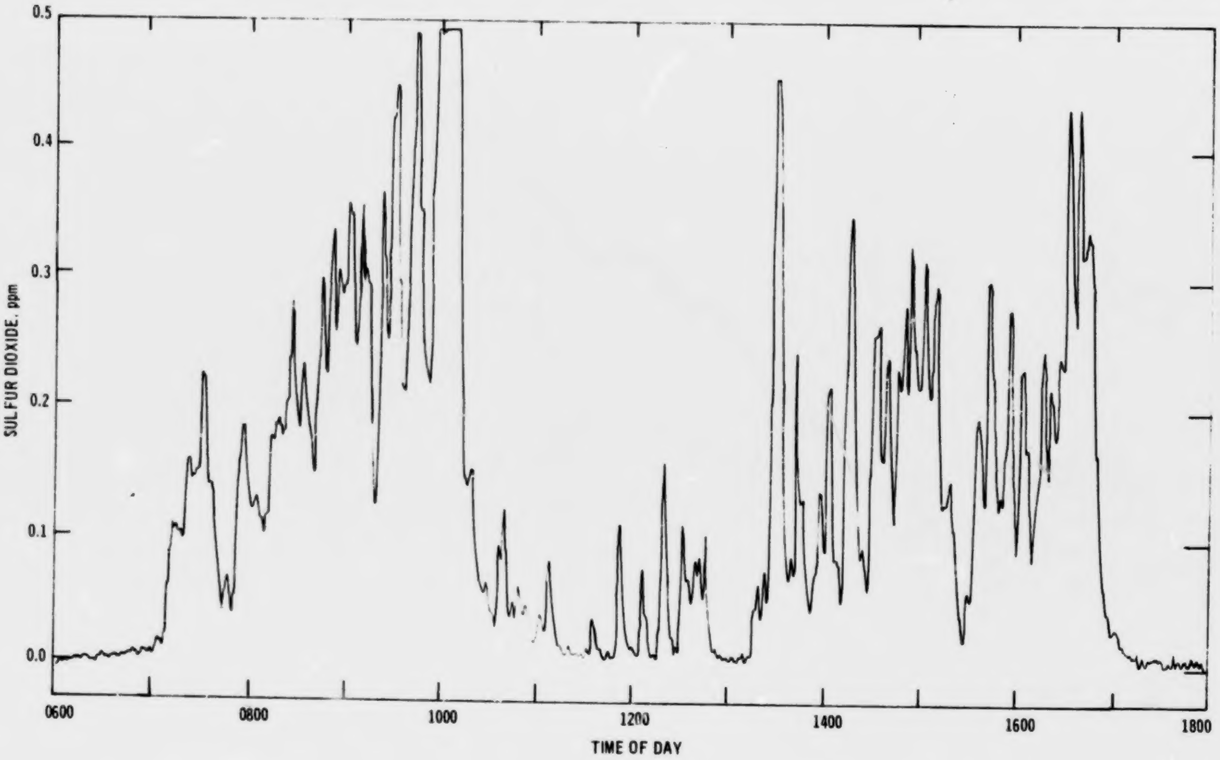


Figure 1-19. Continuous recording of SO_2 concentration for 0800 to 1800 hours on September 12, 1970.

Static Sulfation Measurements

Sulfation plates[43] were used to measure sulfur dioxide activity (sulfation rate) throughout the study area. This static monitor consists of a small plastic dish filled with an absorbing paste, primarily lead peroxide. Atmospheric sulfur dioxide is absorbed upon contact with the paste and held chemically until the sample can be returned to the laboratory for total sulfate analysis.

Monthly and seasonal results are presented in Table A-2 (Appendix A). These values range from a high of 41 micrograms per square centimeter per day (μg/cm^2-day) to only 1 μg/cm^2-day. Sulfation values obtained on the tree farms were generally low, reflecting minimal pollution levels. High short-term concentrations, however, such as those experienced at the Stony River Farm would not necessarily result in elevated monthly sulfation rates since the latter measurement averages concentrations over a much longer period.

Figure 1-20 shows isopleths of SO_2 levels based on average sulfation rates from the data obtained at each station. Values greater than 3 μg SO_2/cm^2-day were mainly confined within 4 miles of the three major pollution sources, except in the northern portion of Garrett County where the extended sulfation isopleths may reflect the influence of wind direction in transporting pollutants from more distant sources into the area. Sulfation values of greater than 3 μg SO_2/cm^2-day also occurred at higher-elevation sampling sites in other directions and at some distance from these major pollution sources, particularly in the vicinity of tree farms near Backbone Mountain. For example, average values of 3 to 4 μg/cm^2-day were recorded at sampling locations 405, 431, and 443, all of which were more than 10 miles from the nearest pollution source. These data indicate the importance of considering topography and occurrence of limited vertical diffusion conditions, as well as distance and wind direction frequency, in assessing the impact of pollution in areas more remote from the pollution sources.

NITROGEN OXIDES

Nitrogen oxides (NO_x), particularly nitrogen dioxide (NO_2) and nitric oxide (NO), are important because they are toxic pollutants as well as precursors of photochemical smog. Nitric oxide is produced by the fixation of nitrogen and oxygen at high combustion temperatures; it is subsequently oxidized to NO_2 in the ambient atmosphere.

Continuous measurements for NO_x were made by means of colorimetric analyzers employing a potassium permanganate scrubber in the sample air intake line. Nitric oxide in the air was oxidized to NO_2 and measured along with the ambient NO_2 by means of the Saltzman colorimetric technique. Maintenance problems were experienced with these analyzers, and missing data can be attributed to instrument malfunctions. Daily maintenance and static calibration checks were performed on all instruments, however, and dynamic calibrations were made several times during the summer.

Hourly sampling results are presented in Table 1-8 Although the data are not continuous, results indicate that average concentrations of NO_x were extremely low--less than 0.01 ppm at all locations. The maximum hourly value recorded during the period of study was only 0.08 ppm at Stony River Farm. Even lower maximum values of 0.02 and 0.03 ppm were recorded at Steyer No. 2 and Weise-McDonald Farms, respectively.

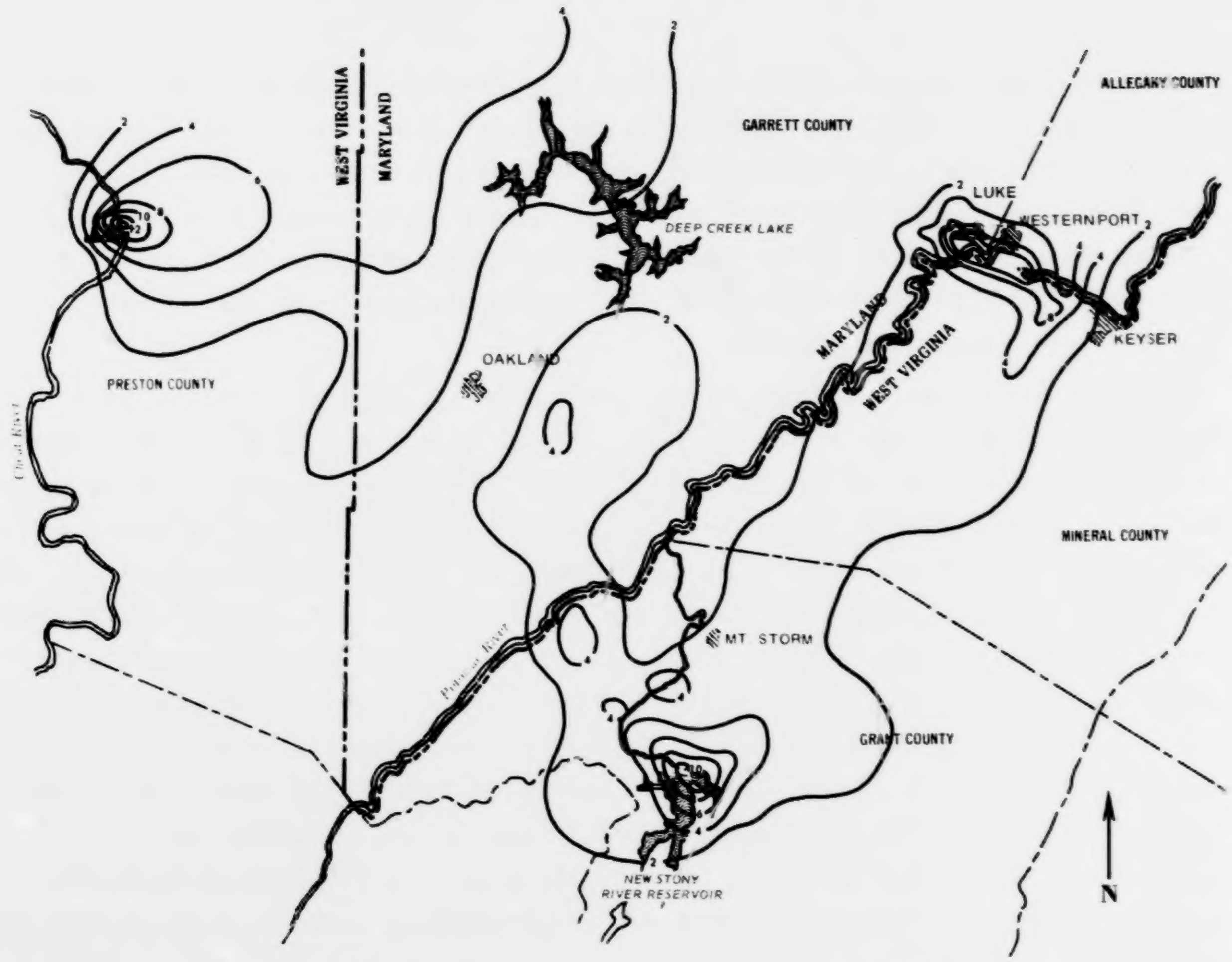

WEST VIRGINIA
MARYLAND
GARRETT COUNTY
ALLEGANY COUNTY
DEEP CREEK LAKE
LUKE
WESTERNPORT
KEYSER
OAKLAND
PRESTON COUNTY
MARYLAND
WEST VIRGINIA
MINERAL COUNTY
MT STORM
GRANT COUNTY
NEW STONY RIVER RESERVOIR
N

Figure 1-20. Distribution of sulfation rates ($\mu g\ SO_2/cm^2$-day).

Table 1-8. SUMMARY OF HOURLY NITROGEN OXIDES MEASUREMENTS, MAY 28 THROUGH SEPTEMBER 27, 1970

Station	No. of observations	Concentration, ppm		Percent observations equal to or exceeding	
		Maximum value	Average value	0.02 ppm	0.05 ppm
1 - Stony River	1,958	0.08	<0.01	1.9	0.4
2 - Steyer No. 2	1,156	0.02	<0.01	1.3	0.0
3 - Weise-McDonald	1,362	0.03	<0.01	4.8	0.0

The national air quality standards proposed for nitrogen oxides are 100 micrograms per cubic meter (0.055 ppm) for annual mean values and 250 micrograms per cubic meter (0.135 ppm) for 24-hour concentrations, not to be exceeded more than once per year. Concentrations in the study area are near background levels, so that they are not likely to cause adverse effects and should not contribute much to the formation of photochemical oxidants.

OXIDANTS

Oxidants are a class of pollutants derived from photochemical reactions involving hydrocarbons and nitrogen oxides. Ultraviolet radiation from sunlight provides energy to initiate reactions between these constituents that produce ozone (the principal component), peroxyacyl nitrates (PAN), and various other oxidant radicals. Concentrations normally follow both a diurnal and seasonal pattern, with maximum concentrations occurring during hours and seasons of maximum solar intensity.

Colorimetric analyzers employing the neutral buffered-potassium iodide technique were located at the three tree farms to measure oxidants. Chromium trioxide filter-paper scrubbers were placed in the air-sample intake of each instrument to minimize interference from reducing agents such as SO_2. Daily electronic and static checks were performed and each instrument was dynamically calibrated several times during the study period.

Relatively high oxidant levels were recorded at all three locations. Table 1-9 indicates a maximum hourly value of 0.15 ppm recorded at Stony River Farm, with values of 0.13 ppm recorded at the other two locations. Four-month average concentrations of 0.05 ppm or greater were observed at all three stations. Significantly, during the study period the oxidant readings did not always follow the classic diurnal pattern in which maximum values occur during maximum solar intensity. Instead, some of the highest recorded values occurred during late evening to midnight.

Table 1-9. SUMMARY OF HOURLY OXIDANT MEASUREMENTS,
MAY 29 THROUGH SEPTEMBER 28, 1970

Station	No. of observations	Concentration, ppm		Percent observations equal to or exceeding	
		Maximum value	Average value	0.06 ppm	0.10 ppm
1 - Stony River	1,782	0.15	0.06	60.8	5.7
2 - Steyer No. 2	2,351	0.13	0.05	47.0	3.0
3 - Weise-McDonald	1,911	0.13	0.06	46.0	3.6

In late August 1969, additional measurements were made to verify the oxidant readings being obtained and to determine the percentage of the oxidant due to ozone. A chemiluminescence instrument, specific for ozone, was placed at the Steyer No. 2 Farm to operate in parallel with the colorimetric analyzer. Ambient air was sampled simultaneously by both instruments from August 26 through September 9, 1970. Results showed that virtually all of the oxidant present was ozone. In fact, the chemiluminescence reading occasionally exceeded the colorimetric reading, possibly due to slight calibration inaccuracies. A maximum hourly measurement of 0.13

ppm was recorded on the chemiluminescence instrument during this 2-week period, with an average concentration of 0.06 ppm occurring. Thus, oxidant levels during this study period exceeded the levels of 0.01 to 0.05 ppm that have previously been reported for nonurban areas.

The diurnal variation of ambient ozone concentrations measured at the Steyer No. 2 Farm for the day (August 12) during which the maximum hourly concentration of 0.13 ppm was reached is shown in Figure 1-21. The long-term pattern or the mean diurnal variation of ozone/oxidant for the period August 26 to September 9 is illustrated in Figure 1-22. The average concentration (0.06 ppm) for the 2-week period approximated the 4-month study period average, and the diurnal change is typical of the pattern observed at all the stations where oxidants were measured.

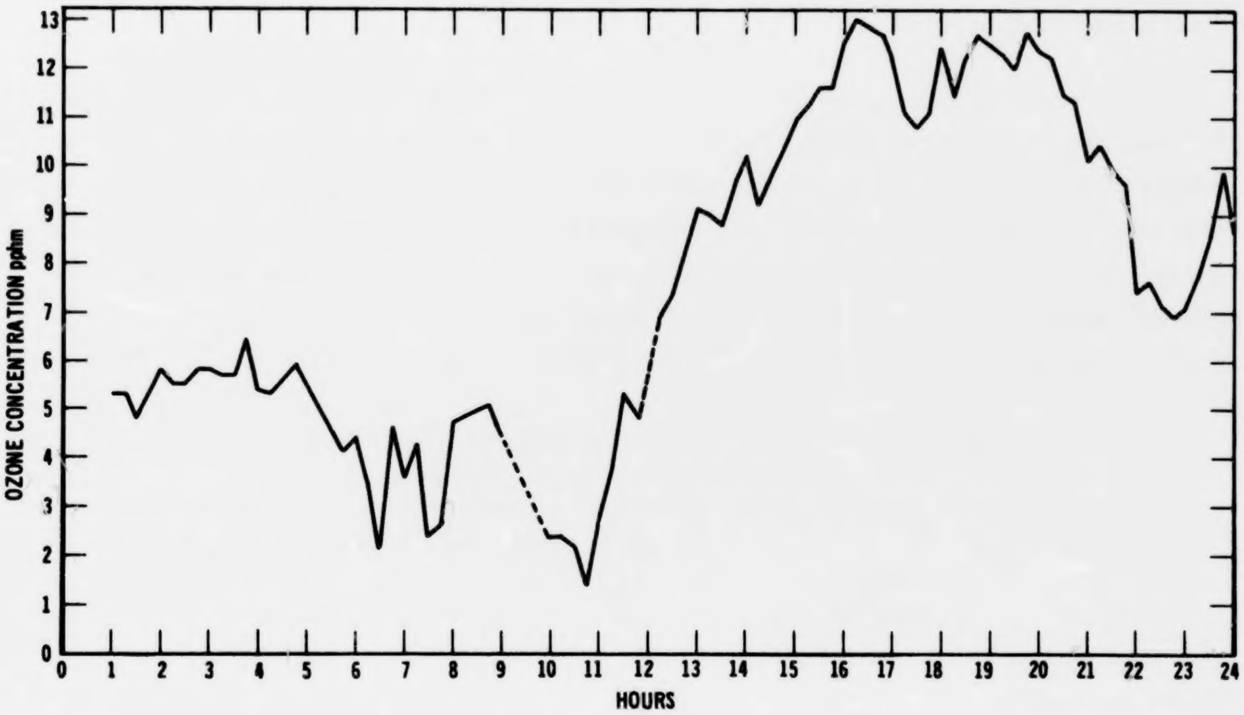


Figure 1-21. Diurnal variation of ozone on August 26, 1970.

Air Quality Criteria for Photochemical Oxidants[23] cites certain levels of oxidants for which the following effects have been reported to occur: (1) adverse health effects on athletes at 0.03 to 0.3 ppm, (2) eye irritation at 0.10 ppm, and (3) adverse effects to sensitive vegetation at 0.05 ppm. Oxidant concentrations recorded during this study in many instances equaled or exceeded these levels.

The national air quality standard proposed for photochemical oxidants is 125 micrograms per cubic meter (0.06 ppm) for a maximum 1-hour concentration, not to be exceeded more than once per year. About 60 percent of hourly oxidant values measured

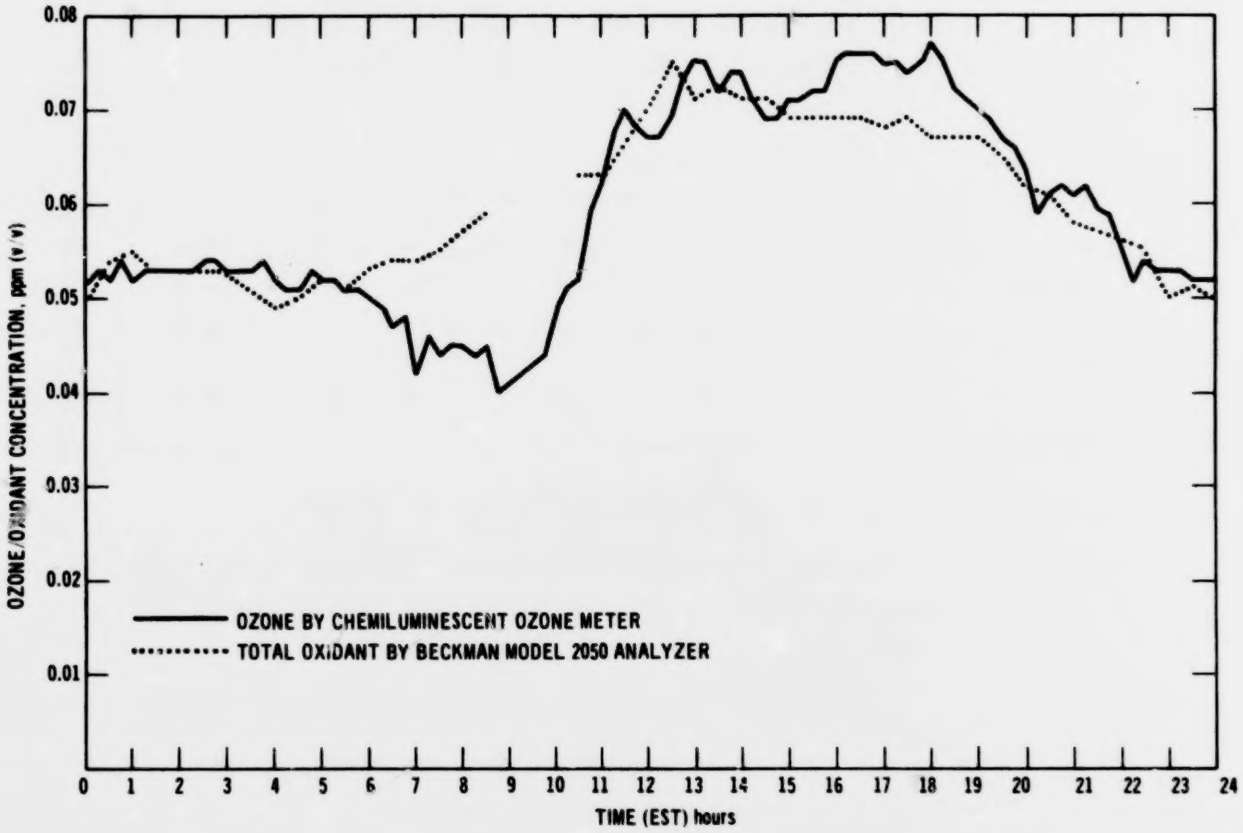


Figure 1-22. Mean diurnal variation of ozone/oxidant for August 26 to September 9, 1970.

over the 4-month growing season in the study area were above this level; more than 5 percent of the hourly readings were greater than 0.10 ppm.

PARTICULATE MATTER

Particulate matter in the atmosphere is generally classified according to particle size. Larger particles greater than 10 microns in diameter tend to settle rapidly from the air and are classified as settleable; particles that are smaller tend to remain airborne for longer periods of time, and are classified as suspended.

Suspended Particulate Matter Measurements

High-volume air samplers were used to measure suspended particulate concentrations at the three tree-farm sites in the study area. Every other day 24-hour filter-paper samples were collected. Results, expressed in micrograms per cubic meter ($\mu g/m^3$), are presented in Table 1-10.

Air Quality Criteria for Particulate Matter[44] indicates that levels greater than 80 $\mu g/m^3$ annual geometric mean may cause adverse effects on health, and 60 $\mu g/m^3$ annual geometric mean may cause adverse effects on materials. The national air

Table 1-10. CUMULATIVE PERCENT FREQUENCY OF OCCURRENCE OF DAILY-AVERAGE SUSPENDED PARTICULATES, JUNE 13 THROUGH SEPTEMBER 28, 1970

Location	Number of observations	Concentration, μg/m^3								
		Minimum value	Percent of time concentration exceeded					Maximum value	Arithmetic mean	Geometric mean
			90	75	60	25	10			
1 - Stony River	47	26	28	36	44	70	95	120	54.6	50.2
2 - Steyer No. 2	54	16	26	42	48	69	91	101	55.0	50.7
3 - Weise-McDonald	59	21	21	40	48	75	100	130	59.1	54.5

quality standards proposed for particulate matter are as follows:

Primary - 75 micrograms per cubic meter for annual geometric mean and 260 micrograms per cubic meter for a maximum 24-hour concentration not to be exceeded more than once per year.

Secondary - 60 micrograms per cubic meter for annual geometric mean and 150 micrograms per cubic meter for a maximum 24-hour concentration not to be exceeded more than once per year.

Geometric mean values recorded during this 4-month study period did not exceed any of these levels. Instead they were generally low, only slightly higher than values expected in a nonurban area.

Settleable Particulate Measurements

An index of settleable particulate matter was obtained through a limited network of dustfall containers placed principally on the tree farms and adjacent to the VEPCO Power Plant. After a month's exposure, the plastic containers were removed and their contents gravimetrically analyzed.

Monthly and seasonal settleable particulate values expressed in grams per square meter per month (g/m^2-mo) are presented in Table A-3 (Appendix A). A maximum monthly value of 33 g/m^2 (94.8 tons/mi^2) and an average seasonal value of 17 g/m^2-mo (48.62 tons/mi-mo) were recorded at Station 409, which is located approximately 0.75 mile south-southeast of the power plant. High readings were also obtained at Stations 413 and 433, both within 4 miles of the power plant.

A comparison of values measured in the study area with national averages obtained by the Interstate Surveillance Project (ISP) Network[45] in 1967 and 1968 showed that 13 locations in the study area exceeded the rural ISP average of 2.3 g/m^2-mo (6.5 tons/mi^2-mo). The ISP average of 5.1 g/m^2-mo (14.6 tons/mi^2-mo) for commercial areas was exceeded at five locations, and the industrial average of 6.6 g/m^2-mo (18.9 tons/mi^2-mo) was exceeded at three locations

Figure 1-23 shows geographic distribution of settleable particulates in terms of seasonal mean values. Measurements were taken at only 24 sampling locations, a number considered insufficient to accurately determine the distribution of dustfall levels. The distribution of settleable particulates around the Mt. Storm Power Plant was similar to the pattern of sulfation rates, with relatively higher dustfall values extending to the Stony River Farm (Station 433).

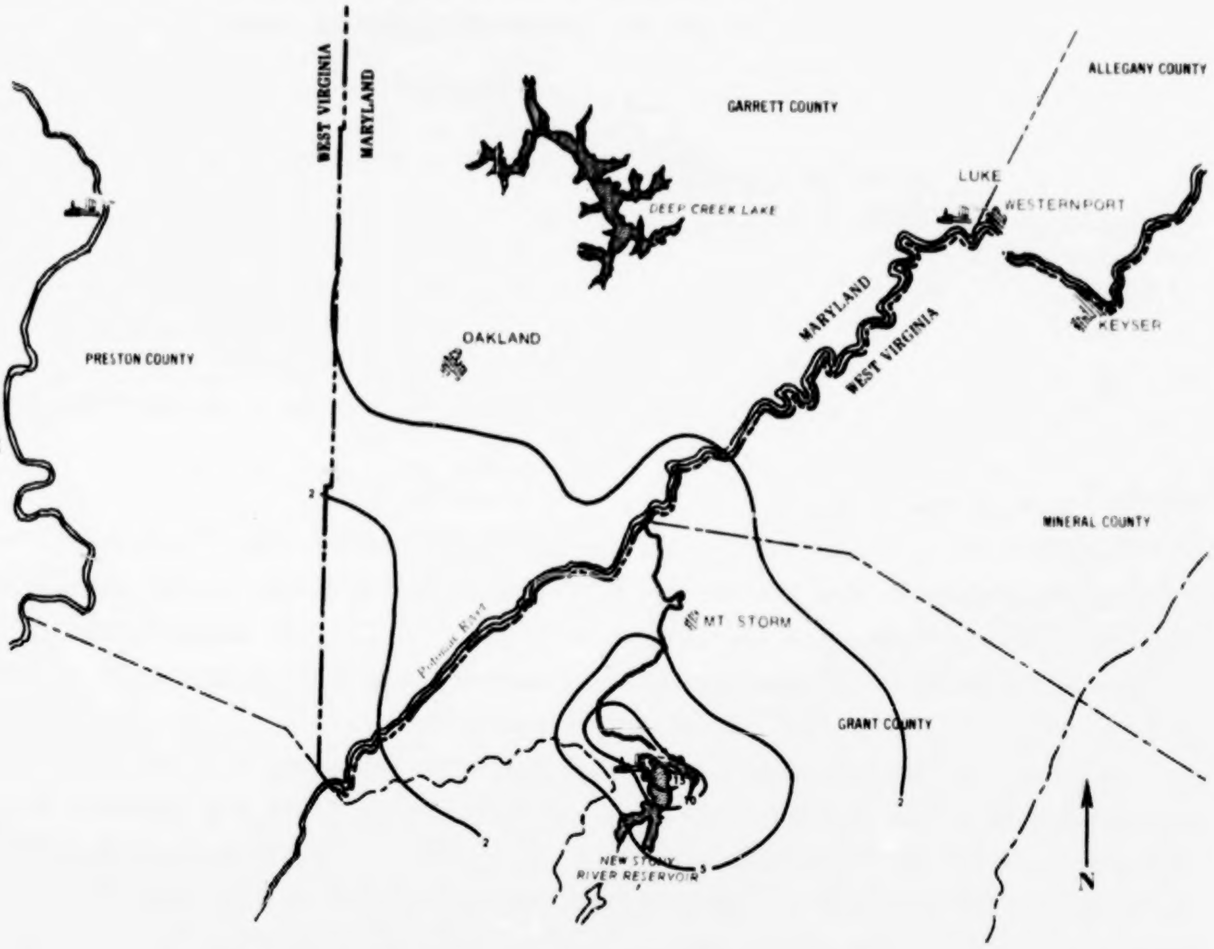

WEST VIRGINIA
MARYLAND
GARRETT COUNTY
ALLEGANY COUNTY
DEEP CREEK LAKE
LUKE
WESTERNPORT
KEYSER
PRESTON COUNTY
OAKLAND
MARYLAND
WEST VIRGINIA
MINERAL COUNTY
MT STORM
GRANT COUNTY
Potomac River
NEW STONY RIVER RESERVOIR
2
2
2
5
10
15
N

Figure 1-23. Distribution of dustfall rates (g/m^2-mo).

FLUORIDES

Fluorides are released as both gaseous and particulate pollutants from certain manufacturing processes that use fluoride-containing raw materials and from the combustion of large quantities of solid fuels containing trace fluorides. Fluoride is an active phytotoxin and can affect sensitive vegetation at very low concentrations.

Total Fluoride Measurements

Total fluorides (gaseous and particulate) were determined at the three tree-farm stations by means of 24-hour filter-paper samples collected on 4-inch-diameter Whatman No. 541 filters impregnated with sodium formate. Extractions were made with a sodium citrate solution, and measurements were made with a specific ion electrode.

Fluoride values obtained with this method, reported in parts per billion (ppb), are summarized in Table 1-11. A complete listing of all the data appears in Table A-5 (Appendix A). Average concentrations at the three locations ranged from 0.06 to 0.08 ppb, with no significant difference between locations.

Table 1-11. CUMULATIVE PERCENT FREQUENCY OF OCCURRENCE OF DAILY-AVERAGE TOTAL FLUORIDE, MAY 28 THROUGH SEPTEMBER 28, 1970

Location	Number of observations	Concentration, ppb							
		Minimum value	Percent of time concentration exceeded					Maximum value	Arithmetic mean
			90	75	50	25	10		
1 - Stony River	50	0.03	0.039	0.047	0.060	0.075	0.091	0.15	0.06
2 - Steyer No. 2	53	0.01	0.033	0.044	0.060	0.082	0.110	0.33	0.07
3 - Weise-McDonald	56	0.02	0.035	0.048	0.070	0.100	0.138	0.39	0.08

Static Fluoride Measurements

Static monitors consisting of a fluoride-reactive medium (small circle of sodium-formate-impregnated Whatman No. 41 filter paper) inserted inside a plastic dish were exposed throughout the study area. These plates were mounted with the exposed surfaces of the filter paper facing downward. After a 30-day exposure, the samples were returned to the laboratory for analysis.

Monthly and seasonal mean fluoridation values in nanograms of fluoride per square centimeter per day (ng F/cm^2-day) are presented in Table A-6 (Appendix A). Seasonal mean values ranged from 3 to 56 ng F/cm^2-day with an average value of 9 ng F/cm^2-day for the 15 tree-farm sampling locations and 13 ng F/cm^2-day for the remainder of the sampling locations.

Figure 1-24 shows the seasonal mean geographic distribution of the fluoridation rates. The relative geographic distribution of fluoridation is similar to sulfation, which indicates that the sources of fluorides and sulfur dioxide are the same.

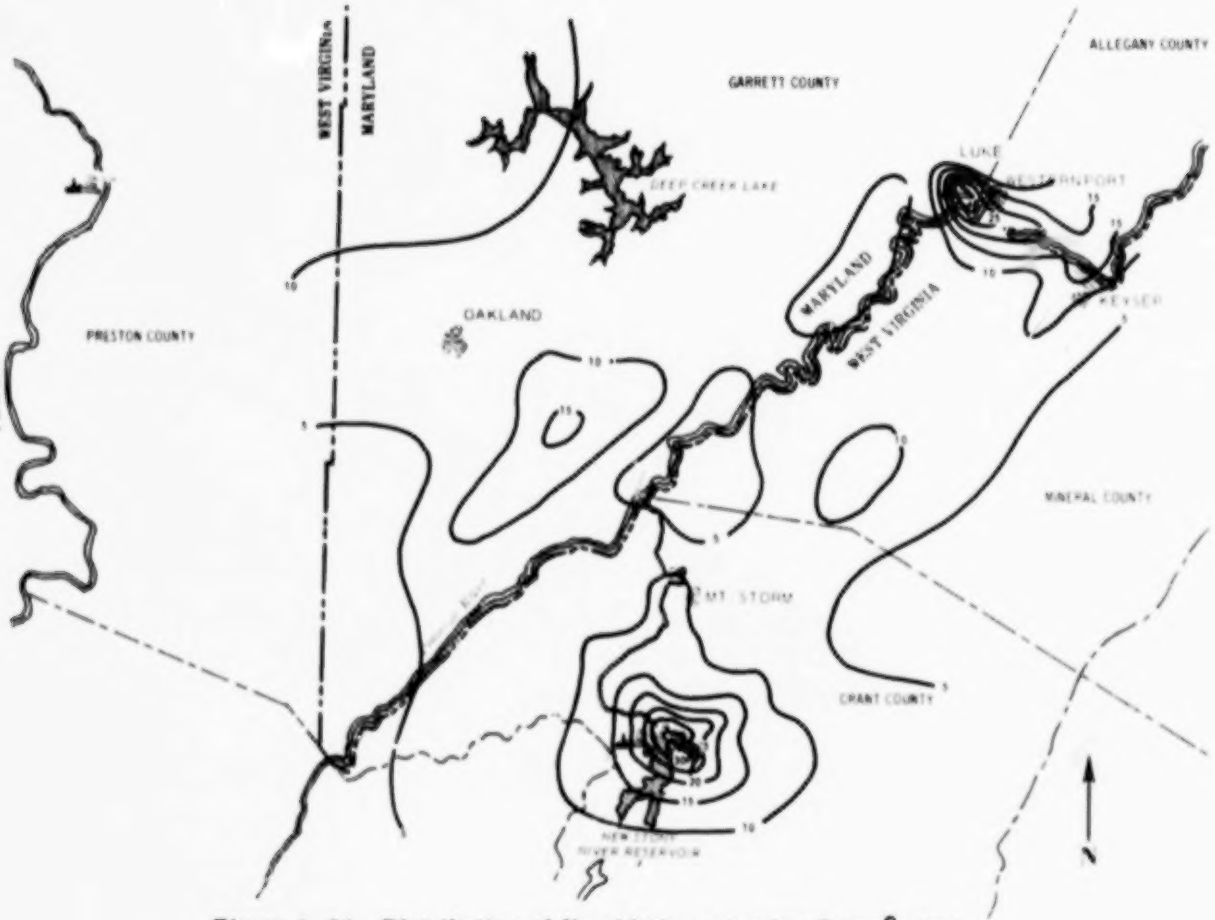

WEST VIRGINIA
MARYLAND
GARRETT COUNTY
ALLEGANY COUNTY
DEEP CREEK LAKE
LUKE
WESTERNPORT
KEYSER
PRESTON COUNTY
OAKLAND
MARYLAND
WEST VIRGINIA
MINERAL COUNTY
MT. STORM
GRANT COUNTY
NEW STONY RIVER RESERVOIR
10
5
15
20
N

Figure 1-24. Distribution of fluoridation rates (ng F /cm^2-day).

BLANK PAGE

VII. ANALYSIS OF POLLUTANT DISTRIBUTION AND IMPACT

Review of the vegetation damage observations and the air pollutant measurements suggests that sulfur dioxide, oxidants, and settleable particulates are the pollutants of primary concern in the Mt. Storm area. Evidence indicates that sulfur dioxide and oxidants are responsible for extensive tree damage, and fly ash has been suggested as being a possible contributor to one type of tree injury as well as a soiling nuisance to residents in the area.

The sources of sulfur dioxide and particulate matter are identifiable, but the sources of the relatively high oxidant levels encountered are not clearly established. Both ground-level and upper-air measurements are still required to identify the sources and determine the reactions producing the oxidants.

The major sources of sulfur dioxide and particulate matter in the Mt. Storm area are the Mt. Storm Power Plant and the Westvaco pulp mill. Power plants outside the area that could have an appreciable effect on air quality of the area are located at Rivesville, Albright, and Fort Martin in West Virginia and at Hatfield Ferry in Pennsylvania. Other emission sources discussed earlier in this report are not considered here because their emissions are judged too small and localized to have a regional impact. These include coal used for home heating, the smoldering "gob piles" near old mines, and the charcoal plant.

In assessing the contribution of the various emission sources to air pollution levels in the Mt. Storm area and the potential for tree farms being affected, it is necessary to consider the expected temporal and spatial variation of pollutants about the area over an extended period of time that corresponds to the several years required for Christmas-tree growth. For this assessment, use is made of atmospheric transport and diffusion models, which allow calculation of concentrations at particular locations of air contaminants that originate at specific sources. These models are employed in a manner that takes into account meteorologic and topographic aspects of the region. They are particularly useful in establishing the possibility and probability of certain concentrations of air contaminants being attained at a specified location over a period of time.

These calculations, as well as evaluation of meteorological conditions existing at times when high concentrations of SO_2 were measured, and at times when tree damage indicative of SO_2 fumigation occurred, demonstrate the probability of SO_2

emissions from the Mt. Storm Power Plant producing ground-level SO_2 concentrations capable of affecting tree farms in the area.

LONG-TERM DISTRIBUTION OF SULFUR DIOXIDE

Application of Diffusion Model

A simplified transport and diffusion model was employed to assess the relative long-term effects of six sulfur dioxide sources that could make a significant contribution to air pollution in the Mt. Storm area. Such a long-term application of diffusion techniques has the advantage of averaging out short-term and periodic variations in transport and dispersion patterns resulting from terrain or other effects. Relative contribution was calculated at three tree-farm sampling sites. The SO_2 sources and measurement sites are identified and the results are given in Table 1-12. The Gaussian plume model described by Turner[46] was used with the following assumptions:

1. At each receptor, the ground-level centerline concentration was computed for each of the six sources. The resulting values were then prorated by the percent frequency of occurrence of wind direction (16 points) that would transport effluent from each source directly to the receptor. Correspondingly, the average wind speed for each appropriate wind direction was used initially in computing centerline concentration. The relative concentration estimates thus derived were converted to a percentage basis to indicate the relative percent contribution of each source.
2. The Pittsburgh 1000-foot, 5-year seasonal wind data given in Table 1-1 were used.
3. Stability class "C" was used to determine vertical and lateral dispersion parameters. This "slightly stable" class is considered to provide a reasonable estimate of average atmospheric stability conditions in the area considering the roughness of the terrain.
4. Plume rise was applied after Briggs[47] for each of the six sources. The calculated plume rise was less than the height of the intervening mountains, except for that of the Mt. Storm Power Plant; hence, surface releases were assumed for the other five.
5. Sources were assumed to operate at installed capacity.
6. Emissions of SO_2 for each source were computed with the assumption that the coal consumed had a 2 percent sulfur content.

Table 1-12. MAJOR SO_2 SOURCES, THEIR LOCATIONS RELATIVE TO THREE AIR MONITORING SITES, AND PERCENT CONTRIBUTIONS TO TOTAL SO_2 RECEIVED BY EACH SITE DURING AN AVERAGE GROWING SEASON

Receptor data	Source					
	Westvaco Mill at Luke, Md.	Mt. Storm, W. Va.	Rivesville, W. Va.	Albright, W. Va.	Ft. Martin, W. Va.	Hatfield Ferry, Pa.
Bearings and distances from:						
Site No. 1, degrees	034	162	295	316	312	324
miles	21	2	50	28	49	54
Site No. 2, degrees	052	189	285	295	300	315
miles	12	12	49	24	45	48
Site No. 3, degrees	093	171	271	270	301	311
miles	14	21	44	17	37	39
1969 installed capacity, mw	a	1,160	175	278	1,152	576[b]
Relative SO_2 contribution, %						
Site No. 1	1	92	1	2	3	1
Site No. 2	9	65	2	11	8	5
Site No. 3	7	28	4	31	20	10
1973 projected capacity, mw	a	1,715	175	278	1,152	1,656
Relative SO_2 contribution, %						
Site No. 1	1	91	1	2	2	3
Site No. 2	7	68	2	8	6	9
Site No. 3	5	30	3	23	15	24

[a] Combined power plant and process emissions of sulfur dioxide are estimated to be 608 g/sec.

[b] Plant facility recently expanded to 1016-mw capacity.

It is evident from Table 1-12 that locations within a 12-mile radius of the Mt. Storm Power Plant are affected primarily by that source. Under the projected 50 percent increase in power production for 1973, the impact of Mt. Storm Power Plant will be materially greater, and the circle of potential contamination will be expanded over a significantly larger area of both Maryland and West Virginia.

Potomac River Valley Airflow Study

Also pertinent to analysis of the impact of sources in the area was a special study of the airflow in the valley of the North Branch of the Potomac River carried out in 1970. Wind measurements were taken along the Potomac River Valley to ascertain whether the Luke pulp mill effluents could appreciably affect tree farms upriver from the plant. Up-valley winds required to transport significant emissions to the area of the farms were seldom continuous over that region of the valley. Only infrequently, when the overall pressure pattern drove a wind from the northeast, could the effluent transported to the farm be of any significance. The study data are presented in more detail in Appendix C.

SHORT-TERM DISTRIBUTION OF SULFUR DIOXIDE

Impact and Analysis

In contrast to the long-term effect resulting from large point source emissions, peak short-term concentrations, particularly those associated with inversion breakup fumigations, do not necessarily decrease with increasing distance from the source within a range of about 15 to 20 miles. In fumigation situations the distance and magnitude of the peak concentrations are primarily governed by the stack height and transport wind speed; impact in the absence of topographic constraints tend to be random in nature.

The temporal and spatial distribution of short-term concentrations in the Mt. Storm area contrasts with the less extreme variations typically found in urban environments having a multiplicity of pollution sources. This distribution about the area affected by a single large power plant is significant both in terms of the potential for vegetation damage and difficulty in obtaining representative air quality data. The following sections are descriptive of the short-term ground-level pollution episodes and related impact associated with emissions from large SO_2 sources.

Acute Injury to Pine Trees

An insight into the nature of at least one type of short-term impact of sulfur dioxide was recorded during the course of investigation of possible pollution in the study area. Severe tip burn characteristic of SO_2 fumigation at the Steyer No. 2 Christmas tree farm was noted in November 1969. This observation was significant because the period during which readily perceptible injury occurred was clearly constrained to the 4-week period ending on November 6, 1969. Concurrent wind data were examined to determine whether meteorological conditions during any part of that time were consistent with and suggestive of fumigation of that farm by the plume from the Mt. Storm Power Plant.

A review of weather records indicated that the damage probably occurred on October 30 and 31. At that time, observations at Pittsburgh indicated that very stable air existed beneath a persistent inversion. The stable air mass confined by an inversion layer would have restricted the rise of a plume to the lower 1,200 to 1,600 feet above the surface for the 2-day period. Mean winds in this layer varied in speed from 9 to 19 miles per hour, and in direction between southeast and south-southwest. These conditions were substantiated by detailed upper-air measurements obtained during the same 2-day period on another study being conducted by APCO in western Pennsylvania. Under the existing conditions, the plume from the Mt. Storm Power Plant could have impacted on Steyer No. 2 Farm during part of the above 2-day period.

Assuming the Mt. Storm plant operated at installed capacity with 2 percent sulfur coal, Pooler's formula[48] for a limited mixing situation was used to estimate centerline concentrations 12 miles downwind (the distance between the Mt. Storm Power Plant and Steyer No. 2 Farm). These calculations indicate that with wind speed of 10 miles per hour, maximum SO_2 concentrations of 0.77 ppm would be obtained, whereas with an 18-mile-per-hour wind speed, 0.43 ppm would occur.

Wind direction during the period was very steady and shifted slowly. It was quite probable that the farm was subjected to high SO_2 levels for a significant portion of the 2-day period.

Aerial Measurement of Sulfur Dioxide

An aircraft and mobile van survey of pollution during the period from November 18 through 23, 1969, is reported in Appendix C. An instrumented helicopter measured the SO_2 concentration in the Mt. Storm Power Plant plume near Steyer No. 2 Farm, over 10 miles (16 km) downwind, at 0.23 ppm. At this same time up to 0.10 ppm SO_2 was measured in the northwest corner of Garrett County; this SO_2 was apparently from sources in West Virginia and Pennsylvania. In the Piedmont - New Creek section of the Potomac Valley, 0.38 ppm SO_2 was found beneath a shallow, strong inversion. This SO_2 was thought to have originated in Luke, Maryland.

Correlation of Peak Sulfur Dioxide Concentrations and Wind Direction

Sulfur dioxide levels were continuously monitored at the three farm sites—Stony River, Steyer No. 2, and Weise-McDonald—from May 28 through September 28,

1970. There were 25 incidences in which the hourly average concentration of SO_2 equalled or exceeded 0.05 ppm at one or more of the three monitoring sites. These cases are tabulated in Table 1-13 according to the prevailing wind direction. Wind directions during the period of elevated SO_2 levels fall into one of three distinct groups: northeast, south, and west through northwest. The SO_2 values shown in the table are the highest hourly average concentrations recorded at each site during the case period indicated. Only a single case with northeasterly wind was found, but 14 cases occurred with southerly and 10 with westerly airflow. During the sole northeasterly wind case, Station No. 2 reached 0.07 ppm SO_2, and Station No. 1 recorded no SO_2. (Station No. 3 was not operating.)

Table 1-13. PEAK 1-HOUR AVERAGE SO_2 CONCENTRATIONS ≥ 0.05 PPM GROUPED BY PREVAILING WIND DIRECTION

Case No.[a]	South			West through northwest			Northeast		
	No. 1	No. 2	No. 3	No. 1	No. 2	No. 3	No. 1	No. 2	No. 3
1	0.16	0.13	0.01	0.04	0.01	0.05	0.00	0.07	b
2	0.13	b	0.01	0.00	0.07	0.03			
3	0.10	b	0.02	0.03	0.08	b			
4	0.03	0.06	0.02	0.02	0.11	0.04			
5	0.17	0.00	0.00	0.06	0.05	0.02			
6	0.03	0.05	0.00	0.00	0.00	0.07			
7	0.11	0.01	0.00	0.02	0.04	0.10			
8	0.18	0.00	0.00	b	0.02	0.06			
9	0.13	0.01	0.01	0.01	0.02	0.08			
10	0.12	0.00	0.00	0.10	0.00	0.07			
11	0.36	0.00	0.00						
12	0.06	0.00	0.02						
13	0.09	0.03	0.01						
14	0.15	0.00	0.00						
Mean	0.13	0.02	0.01	0.03	0.04	0.06	0.00	0.07	b

[a] Case determined by level of ≥ 0.05 ppm occurring at one or more stations.
[b] Station not operating.

The 14 south-wind cases were characterized by significant SO_2 levels at Station No. 1; little more than a trace was recorded during these times at Stations No. 2 and 3. Levels of SO_2 at all sites were lower with westerly winds than with south winds. The SO_2 concentration during westerly winds tended to be higher at Stations No. 2 and 3 than at Station No. 1. These data show that, although the area is sometimes subjected to significant levels of SO_2 with a westerly wind and occasionally with northeasterly wind, the highest levels are consistently recorded with a southerly wind flow. Only Station No. 1 recorded readings above 0.10 ppm frequently, and these occurred only when the wind was from the south.

LAPPES Analogy[49]

The Division of Meteorology of the Air Pollution Control Office is conducting the Large Power Plant Effluent Study (LAPPES) in western Pennsylvania, where three mine-mouth generating stations are being put into operation. The topography of this region is similar to that of the Mt. Storm area, and the individual power plants are about the size of the Mt. Storm Power Plant; therefore, reasonable comparisons can be drawn.

Mr. Frank Schiermeier, on-site meteorologist in charge of LAPPES, reported an hourly average SO_2 concentration of 0.35 ppm, a 5-hour average of 0.14 ppm, and peaks to 0.64 ppm were recorded by samplers operated continuously at an airport some distance from the power plants. The suspected source was one of the power plants of the 1,200-megawatt range with two 800-foot stacks installed less than a year earlier about 10 miles from the airport. Higher SO_2 concentrations had been frequently recorded during the LAPPES project by means of helicopter and portable bubbler sampling.[50]

This information is significant relative to Mt. Storm by verifying the potential, although infrequent occurrence of high peak concentrations at ground-level locations some distance from the source. Even though inversion-breakup fumigations probably occur on most mornings during the growing season somewhere in the Mt. Storm area, it is unlikely that samplers operated at a fixed location less than a third of a year would have been placed in a position to record the high SO_2 concentrations that must have occurred occasionally. Furthermore, westerly winds were more dominant during the period. This may have abnormally limited southerly wind cases and correspondingly inversion-breakup situations occurring with this wind direction. A southerly wind was necessary to carry the power plant effluent toward the air monitoring sites.

Pooler and Niemeyer[51] reported that a plume from one of the LAPPES cooperating power plants was followed by an instrumented helicopter during an inversion breakup to a distance 29.2 miles from the plants. Surface-level SO_2 values exceeded 0.20 ppm at a distance of between 19.9 and 26.1 miles; a peak of 0.36 ppm was measured at 22.4 miles. They also found indications of greater ground-level pollution concentrations on ridges than in adjacent lowlands. Many of the more severely damaged tree farms in the Mt. Storm area are located on or near ridge-top level.

The LAPPES project has obtained measurements that confirm the occurrence of substantial ground-level concentrations of SO_2 tens of miles downwind from 1,000-megawatt-class power plants despite the use of tall stacks to disperse the emissions. Project experience also indicates, however, that during any one year, it is unlikely that any one geographic point will be subjected to an extremely high SO_2 level.

Information has been presented that, during the forenoon of about half of the days during the growing season in the Mt. Storm area, an inversion breakup does occur somewhere along a segment of the downwind radii from the Mt. Storm Power Plant. Whether these high concentrations occur at a given point in the area once a year or every few years, the implication is the same. It is extremely unlikely that a tree farm anywhere within the area of impact of the Mt. Storm plant will bring a single crop of Christmas trees to maturity without the trees being subjected to short-term SO_2 episodes of sufficient concentration to cause severe injury to sensitive pines.

Since Pooler reported 0.36 ppm SO_2 more than 20 miles downwind from a 1,000 megawatt-class plant, concentrations of this magnitude also should be expected in the Mt. Storm area, with perhaps higher levels at the distance of maximum impact and near the top and on the lee side of ridges. The valleys east of the Allegheny Front Range are much less subject to high SO_2 levels during inversion breakup because of their much lower elevation and the deep layer of air below the plume.

FLY-ASH PROBLEM NEAR MT. STORM POWER STATION

Particulate fallout in the vicinity of coal-burning plants frequently presents a major nuisance by damaging materials and painted surfaces, and contributing to the general dirtiness of the surrounding area. Complaints registered by residents living in Grant County, West Virginia, have indicated that particulate matter from the Mt. Storm Power Plant places an economic burden upon area residents and also affects the aesthetic quality of their environment.

Residents living within 2 miles of the plant reported severe soiling problems as a result of particulate fallout. Windows were coated with dust-like particles; fly ash and particulate matter were deposited on window sills. Windows and doors have to be kept closed regardless of season to minimize the penetration of this dirt into the interior of homes. Exterior finishes of homes and automobiles of residents in the area have deteriorated as a result of constant contact with particulate matter from the plant. Exterior drying of laundry was reported to be impossible because of the high frequency of particulate fallout, and as a consequence, driers have to be utilized.

Residents as far as 9 miles from the plant reported that windows are darkened by particulate matter, and automobiles are frequently covered with fly-ash material. Yards are often coated with particulate matter, and snowfall in this area is frequently turned a dingy gray as a result of this fallout.

The combined effects from particulate fallout in the area tend to place an economic burden on the residents in the form of increased laundry and cleaning costs, as well as property deterioration. In addition, the particulate fallout appears to cause an inconvenience to persons residing as far as 10 miles south-southeast of the power plant.

BLANK PAGE

VIII. REFERENCES

1. Private communication from J. D. Ristroph, Manager - Power Production, Virginia Electric and Power Company, to Fred A. Thayer (representing Dr. F. D. Custer). September 5, 1968.

2. Private communication from P. R. Mateer, Jr., Asst. District Forester, Dept. of Forests and Parks, Oakland, Maryland, to G. T. Helms, National Air Pollution Control Administration, Durham, N. C. February 13, 1970.

3. Private communication from J. A. Porter, District Forester, District II, Dept. of Natural Resources, Romney, West Virginia, to G. T. Helms, National Air Pollution Control Administration, Durham, N. C. February 17, 1970.

4. Thornthwaite, C. W. An Approach Toward a Rational Classification of Climate. Geographical Review, 55-94. January 1948.

5. Private communication from W. J. Moyer, NOAA Climatologist, College Park, Maryland, to H. S. Slater, Air Pollution Control Office, Durham, N. C. December 12, 1970.

6. Private communication from R. O. Weedfall, NOAA Climatologist, Morgantown, West Virginia, to H. S. Slater, Air Pollution Control Office, Durham, N. C. December 16, 1970.

7. West Virginia Climatological Data Bulletins. State Climatologist, National Weather Service Office, NOAA, U.S. Dept. of Commerce, Morgantown, West Virginia.

8. Hosler, C. R. Low-Level Inversion Frequency in the Contiguous United States. Monthly Weather Review, 89(9):319-339. 1961.

9. Holzworth, G. C. Mixing Depths, Wind Speeds, and Air Pollution Potential for Selected Locations in the United States. Journal of Applied Meteorology, 6(6):1039-1044. December 1967.

10. Brandt, C. S. and W. W. Heck. Effects of Air Pollution on Vegetation. In: Air Pollution, 2nd edition, Vol. I, A. C. Stern (ed.). Academic Press, New York - London. p. 401-443. 1968.

11. Haselhoff, E. and G. Lindau. Die Beschadigung der Vegetation Durch Rauch. Borntrager, Berlin. 1903.

12. Holmes, J. A., E. C. Franklin, and R. A. Gould. U. S. Bureau of Mines Bull. 98. 1915.

13. National Research Council of Canada. Effects of Sulfur Dioxide on Vegetation. NRC 815. Ottawa, Canada. 1939.

14. Sheffer, T. C. and G. G. Hedgcock. Injury to Northwestern Forest Trees by Sulfur Dioxide from Smelters. Tech Bull. No. 1117. U. S. Dept. of Agric. Forest Service. 1955.

15. Costonis, A. C. Acute Foliar Injury of Eastern White Pine Induced by Sulfur Dioxide and Ozone. Phytopathology, 60(6):994-999. June 1970.

PRECEDING PAGE BLANK

16. Menser, H. A. and H. E. Heggestad. 1966 Ozone and Sulfur Dioxide Synergism to Tobacco Plants. Science, 153:424-425.

17. Linzon, S. N. The Influence of Smelter Fumes on the Growth of White Pine in the Sudbury Region. Contribution No. 439. Forest Biol. Div., Dept. Agri., Ottawa, Canada. 1958.

18. Wells, A. E. Results of Recent Investigations of the Smelter Smoke Problem. Ind. Engr. Chem., 9:640. 1917.

19. Linzon, S. N. Sulfur Dioxide Injury to Trees in the Vicinity of Petroleum Refineries. Forest Chronicle, 41:245. 1965.

20. Bleasdale, J. K. A. Atmospheric Pollution and Plant Growth. Nature, 169:376. 1952.

21. Berry, C. R. and G. H. Heptuoy. Injury to Eastern White Pine by Unidentified Atmospheric Contaminants. Forest Science, 10:2-13. 1964.

22. Air Quality Criteria for Sulfur Oxides. U. S. DHEW, PHS, EHS, NAPCA. NAPCA Publication No. AP-50. 2nd printing. April 1970.

23. Air Quality Criteria for Photochemical Oxidants. U. S. DHEW, PHS, EHS, NAPCA. NAPCA Publication No. AP-63. March 1970.

24. Setterstrom, C. Effects of Sulfur Dioxide on Plants and Animals. Ind. Engr. Chem., 32:473. 1940.

25. Private communication from Dr. F. D. Custer to N. G. Kirby, Supt., Mt. Storm Power Station. July 5, 1968.

26. Private communication from Dr. F. R. Gouin, Horticulture Dept., University of Maryland, College Park, Maryland, to Dr. F. D. Custer and Virgil T. Steyer, Jr. August 27, 1967.

27. Private communication from Dr. Leon S. Dochinger, Plant Pathologist, U. S. Forest Service Experimental Station, Delaware, Ohio, to Dr. F. D. Custer. October 22, 1969.

28. Evaluation of Suggested Air Pollution Damage to Vegetation in the Vicinity of VEPCO's Mt. Storm Power Station. Report by Dr. Francis A. Wood, Assoc. Prof. of Plant Pathology, Penn. State Univ., Pa. October 1969.

29. Hindawi, I. Preliminary Examination of Damage to Christmas Trees in Vicinity of Oakland, Maryland - Mt. Storm, West Virginia. Report to NAPCA, Durham, N. C. November 1969.

30. Gordon, C. C. Damage to Christmas Trees Near Oakland, Maryland - Mt. Storm, West Virginia. Report to NAPCA. November 1969.

31. Anderson, R. F. Relation of Insects and Mites to the Abnormal Growth of Christmas Trees in Mt. Storm, West Virginia - Oakland, Maryland, Vicinity. Report prepared for APCO, Durham, N. C. December 1970.

32. Wood, F. A. Evaluation of Treatment for Control of Dwarf Needles on Scotch Pine. Report presented at meeting of APCO—State air pollution control officials at Blackwater Falls, W. Va. August 27, 1970.

33. Blokker, P. D. The Atmospheric Chemistry and Long-Range Drift of Sulfur Dioxide. Journal of the Institute of Petroleum. 36(542):71-79. March 1970.

34. Johnstone, H. T. and D. R. Coughanowr. Absorption of Sulfur Dioxide from Air. Ind. Eng. Chem., 30(8):1169–1172. August 1958.

35. Gordon, C. C. Disease Syndrome Occurring at Steyer No. 2 Farm During November 1969. Report to Air Pollution Control Office of U. S. Environmental Agency. March 1970.

36. Thomas, M. D., R. H. Hendricks, and G. R. Hill. Sulfur Metabolism of Plants: Effects of Sulfur Dioxide on Vegetation. Ind. Eng. Chem., 42(11):2231-2235. 1950.

37. Gordon, C. C. Unnatural Accumulation of Sulfur in Conifer Needles: Effects of Hoerner-Waldorf Emissions on Missoula Valley Study. Report to National Air Pollution Control Administration. September 1969.

38. Air Pollution Damage to State Forests. Interagency Report to J. Schueneman, Director, Air Pollution Control Division, Maryland Dept. of Health and Mental Hygiene, from A. R. Bond, State Forester, Maryland Dept. of Forests and Parks. Feb. 1971.

39. Linzon, S. N. Economic Effects of Sulfur Dioxide on Forest Growth. J. Air Pollution Control Association, 21(2):81-86. February 1971.

40. Steam-Electric Power Plant Factors. National Coal Association, Washington, D. C. 1970.

41. Air Quality Criteria for Sulfur Oxides. U.S. DHEW, PHS,EHS, National Air Pollution Control Administration. Washington, D. C. NAPCA Publication No. AP-50. Second printing April 1970.

42. National Primary and Secondary Ambient Air Quality Standards and Air Pollution Control. Federal Register, Part Two, 36(21):1502. January 30, 1971.

43. Huey, N. A. The Lead Dioxide Estimation of Sulfur Dioxide Pollution. J. Air Pollution Control Association, 18(9):610-611. September 1968.

44. Air Quality Criteria for Particulate Matter. U. S. DHEW, PHS, CPEHS, National Air Pollution Control Administration, Washington, D. C. NAPCA Publication No. AP-50. January 1969.

45. Cavender, J. H. et al. Interstate Surveillance Project: Measurement of Air Pollution Using Static Monitors. U. S. Environmental Protection Agency, Air Pollution Control Office, Research Triangle Park, North Carolina (In Press).

46. Turner, D. B. Workbook of Atmospheric Dispersion Estimates. U. S. DHEW, PHS, CPEHS, National Air Pollution Control Administration, Washington, D. C. PHS Publication No. 999-AP-26, 2nd Printing 1969.

47. Briggs, G. A. Plume Rise. Atomic Energy Commission Critical Review Series TID 25075. 1969.

48. Pooler, F. Jr. Potential Dispersion of Plumes from Large Power Plants. U.S. DHEW, PHS, CPEHS, NCAPC. PHS Publication No. 999-AP-16. 1965.

49. Large Power Plant Effluent Study (LAPPES). Volume 1—Instrumentation, Procedures, and Data Tabulations (1968). U.S. DHEW, PHS, EHS, National Air Pollution Control Administration, Raleigh, N. C. NAPCA Publication No. APTD 70-2. June 1970. Volume 2—Instrumentation, Procedures, and Data Tabulations (1967 and 1969). U.S. DHEW, PHS, EHS, National Air Pollution Control

Administration, Raleigh, N. C.. NAPCA Publication No. APTD 0589. November 1970.

50. Private communication from F. Schiermeyer, APCO meteorologist, to Herschel Slater, Division of Meteorology, Air Pollution Control Office of U.S. Environmental Protection Agency, Research Triangle Park, N. C. 1971.

51. Pooler, F. Jr. and L. E. Niemeyer. Dispersion from Tall Stacks: An Evaluation. Paper No. ME-14D, 2nd International Clean Air Congress, Washington, D. C. December 1970.

APPENDIX A.

AIR QUALITY DATA

Table A-1. LOCATION OF STATIC SAMPLING STATIONS

Station number	Pollutant type[a]	MSL elevation	Location description
401	SF	3,350	Stony River Farm; at air monitoring site.
402	SF	2,620	Steyer No. 2 Farm; at air monitoring site.
403	SF	2,590	Weise-McDonald Farm; at air monitoring site.
404	SFD	3,000	W. U. Relay Tower; 1/2-mile SSW of junction of U.S. 50 and W. Va. 42.
405	SF	2,790	U.S. 50; where highway crosses Allegheny Front Mt.
406	SF	3,100	W. Va. State Road 50/2; 2 miles SW of U.S. 50.
407	SFD	2,660	Custer's Home Farm; hilltop level.
408	S	2,260	Elk Garden, W. Va.; near center of town on W. Va. 42.
409	SFD	DI[b]	Kline residence; 1-1/2 miles ESE of VEPCO.
410	SFD	3,400	W. Va. 93; 2 miles west of VEPCO.
411	SFD	3,250	W. Va. 93; 5 miles west of VEPCO.
412	SF	2,980	W. Va. 42; 2-1/2 miles SSE of Mt. Storm, W. Va.
413	SFD	DI	Lakeside; ENE of VEPCO.
414	SF	DI	Bismarck, W. Va.; junction of W. Va. State Road 50/3 and W. Va. 93.
415	SFD	DI	Park Residence, Sherr, W. Va.; 1/4 mile north of junction of W. Va. 42 and W. Va. 93.
416	SFD	DI	Hawk Farm; 3-1/2 miles NNE of Sherr, W. Va.
417	SF	2,600	W. Va. State Road 50/3; near junction with U.S. 50.
418	SF	2,810	W. Va. State Road 50/3; 1.7 miles south of U.S. 50.
419	SF	2,750	Rehoboth Church Cemetery; W. Va. State Road 50/4.
420	S	2,450	W. Va. 42; north of Sulfur City, W. Va.
421	SF	1,300	Shaw, W. Va.; W. Va. 46.
422	SF	1,180	Barnam, W. Va.; W. Va. State Road 46/2.
423	SF	1,220	W. Va. 46; overlooking paper mill at Luke, Md.
424	SFD	920	Westernport, Md.; roof of Municipal Sewage Treatment Plant.
425	SF	900	Md. 135; 1.4 miles south of Piedmont-Westernport Bridge.
426	SF	880	Md. 135; 1.7 miles NW of junction of Md. 135 and U.S. 220.
427	SF	1,100	County Rd. No. 1; west of Beryl, W. Va.
428	SFD	2,750	White Face Farm.
429	SFD	2,640	Weise-McDonald Farm.
430	SFD	2,620	Steyer No. 3 Farm.
431	SF	3,010	Bethleham Rd; where road crosses Backbone Mt.
432	SFD	2,700	Steyer No. 2 Farm.
433	SFD	3,300	Stony River Farm; flat portion of farm.
434	SFD	2,850	Mt. Storm, W. Va.
435	SFD	2,730	Taylors Farm; Kempton Rd.
436	SFD	2,700	Taylors Farm; Shady Dell Rd.
437	SF	2,800	Southeast of Charcoal Plant; north of junction of White Church - Steyer Rd. and A. Riley Rd.
438	SF	2,100	Laurel Run Rd; vicinity of Potomac River.
439	SFD	2,540	Vicinity of Taskers Corner gob pile.
440	SF	2,700	Oak Grove Rd; west of junction with Md. 560.
441	SFD	2,560	Steyer No. 4 Farm.
442	SF	1,600	Blaine, W. Va.; east of W. Va. 42.
443	SFD	2,660	Steyer No. 5 Farm.

[a] S = Sulfation plate; F = fluoridation plate; and D = settleable particulate (dustfall).

[b] DI = Data incomplete.

Table A-1 (continued). LOCATION OF STATIC SAMPLING STATIONS

Station number	Pollutant type[a]	MSL elevation	Location description
444	SFD	2,740	Steyer No. 1 Farm.
446	SF	2,400	Nethken Church Cemetery; W. Va. State Rd. 42/1.
447	SF	1,700	Shallmar, Md.
448	SFD	2,760	Riley Farm.
449	SFD	2,500	Feister's Farm; 1/2 mile south of Crellin, Md.
450	SF	3,160	Fire Tower on Snaggy Mt.
451	SF	2,710	W. Va. State Rd. 50/5; west of Mt. Pisgah, W. Va.
452	SFD	DI	W. Va. 42; between Allegheny Front Mt. and Scherr, W. Va.
453	SFD	DI	Schell residence; south of Scherr, W. Va.
454	SF	1,140	U.S. 50; vicinity of Claysville, W. Va.
455	SF	2,910	W. Va. 42; 1.3 miles SSE of Mt. Storm, W. Va.
456	SF	DI	W. Va. State Rd. 42/1; 1.6 miles SSE of VEPCO.
457	SF	DI	Keplinger residence; W. Va. 42.
458	SF	2,440	Herrington Manor Rd.; vicinity where power lines cross road.
459	S	2,680	Oakland-Sang Run Rd.; west of junction with Bray School Rd.
460	SF	DI	W. Va. State Rd. 42/1; 2.3 miles east of VEPCO.
461	SF	DI	Side road east of W. Va. State Rd. 42/1
462	SF	2,740	Upperman Rd.; between junction of Boiling Springs Rd. and Potomac Camp Rd.
463	SF	3,300	W. Va. State Rd. 90/1; where power line crosses road.
464	SF	DI	Relay Tower; 1.2 miles ENE of VEPCO.
465	S	2,450	W. Va. 42; 1 mile NNW of Sulfur City.
466	S	1,100	Piedmont, W. Va ; 0.4 mile NNE of paper mill.
467	S	1,070	Beryl, W. Va.
468	S	3,252	Kempton Rd. Fire Tower; on ridge of Backbone Mt.
469	S	2,510	Hutton Rd; east of junction with Jackson Lane.
470	S	DI	Off W. Va. State Rd. 45/3; 1.3 miles ESE of Albright Power Plant.
471	S	DI	Off W. Va. State Rd. 45/1; 2.2 miles NE of Albright Power Plant.
472	S	DI	Off W. Va. State Rd.45/1; 7 miles NE of Albright Power Plant.
473	S	DI	W. Va. State Rd. 7/12; across Cheat River from Albright Power Plant.
474	S	2,320	On Md. 560 at Gorman, Md.
476	S	DI	Luke, Md.; 0.2 mile NW of paper mill.
477	S	DI	Junction of W. Va. 2 and W. Va. State Rd. 2/2.
478	S	DI	Keyser, W. Va.
479	S	DI	W. Va. 46; 0.4 mile from paper mill.
480	S	DI	Potomac Camp Rd.; south of junction with N. Hill Rd.

Table A-2. SULFATION NETWORK RESULTS

Sampling station[a]	Sulfation rate, μg SO_2/cm^2-day				
	June	July	August	September	Arithmetic mean
401	5	7	2	4	4
402	3	2	2	2	2
403	2	3	1	1	2
404	2	4	1	1	2
405	4	5	4	3	4
406	3	7	3	4	4
407	3	3	2	3	3
408	-	-	1	1	1
409	12	13	9	13	12
410	3	3	3	2	2
411	1	2	2	1	1
412	4	6	3	4	4
113	5	5	5	10	6
414	4	3	3	5	4
415	5	3	3	3	3
416	3	5	1	2	2
417	1	1	1	1	1
418	-	3	2	2	2
419	2	2	2	1	2
420	2	3	1	2	2
421	1	5	1	1	2
422	1	4	1	1	2
423	29	41	22	35	33
424	6	8	5	8	7
425	13	12	9	9	10
426	15	12	10	13	12
427	6	5	3	4	4
428	7	4	2	4	4
429	3	7	1	2	3
430	1	2	1	2	1
431	4	7	4	2	4
432	4	3	2	2	3
433	5	5	1	2	3
434	2	2	1	2	1
435	1	4	1	1	2
436	1	3	1	1	1

Table A-2 (continued). SULFATION NETWORK RESULTS

Sampling station[a]	Sulfation rate, µg SO_2/cm^2-day				
	June	July	August	September	Arithmetic mean
437	5	3	2	2	3
438	0	5	1	1	1
439	2	5	1	1	2
440	3	2	1	2	2
442	2	-	1	1	1
443	3	7	2	2	3
444	2	6	1	2	3
446	3	3	1	1	2
447	1	2	1	1	1
448	4	5	2	2	3
449	2	4	2	2	2
450	-	6	-	4	5
451	-	4	3	2	3
452	-	8	4	6	6
453	-	3	1	2	2
454	-	5	2	2	3
455	-	-	2	1	1
456	-	8	3	3	4
457	-	-	2	4	3
458	-	5	-	2	4
459	-	5	1	2	3
460	-	-	9	13	11
461	-	-	4	7	6
462	-	-	3	-	3
463	-	-	2	1	2
464	-	-	3	4	3
465	-	-	2	2	2
466	-	-	5	8	7
467	-	-	2	3	3
468	-	-	1	1	1
469	-	-	2	1	2
470	-	-	8	-	8
471	-	-	9	6	7
472	-	-	16	14	15
473	-	-	9	-	9
474	-	-	2	1	2

Table A-2 (continued). SULFATION NETWORK RESULTS

Sampling station[a]	Sulfation rate, μg SO_2/cm^2-day				
	June	July	August	September	Arithmetic mean
476	-	-	-	2	2
477	-	-	-	1	1
478	-	-	-	4	4
479	-	-	-	22	22

[a] Index to station locations given in Table A-1.

Table A-3. SETTLEABLE PARTICULATE NETWORK

Sampling station[a]	Settleable particulate (dustfall), g/m^2-mo				
	June	July	August	September	Arithmetic mean
404	3.8	1.5	1.3	0.7	1.8
407	1.3	1.6	1.6	1.8	1.6
409	33.7	18.7	9.0	6.4	17.0
410	-	1.4	4.4	1.5	2.4
411	1.5	1.7	3.4	1.4	2.0
413	28.0	7.2	4.5	5.2	11.2
415	6.2	7.1	5.4	5.2	6.0
416	-	2.4	3.5	4.2	3.4
424	3.8	5.2	6.8	3.9	4.9
428	1.6	2.4	1.7	1.7	1.9
429	-	2.0	1.7	1.4	1.7
430	1.1	1.2	2.5	1.7	1.6
432	1.2	1.6	3.5	1.2	1.9
433	10.5	12.8	10.7	7.1	10.2
434	4.1	3.3	6.1	-	4.5
435	-	1.2	2.5	1.9	1.9
436	2.3	1.3	2.5	1.7	2.0
439	2.4	1.4	4.1	2.4	2.6
443	2.0	0.9	2.1	1.3	1.6
444	2.3	1.1	3.4	1.5	2.1
448	-	7.2	2.7	-	5.0
449	3.7	2.6	2.7	1.4	2.6
452	-	5.3	5.5	8.1	6.3
453	-	5.3	5.9	1.8	4.3

[a] Index to station locations given in Table A-1.

Table A-4. DAILY SUSPENDED PARTICULATE CONCENTRATIONS
(μg/m³)

	Stony River				Steyer No. 2				Weise-McDonald			
Day	June	July	August	September	June	July	August	September	June	July	August	September
1		83		30	28	100		32	73	130		38
2			37				49				74	
3				46	93	48		80	25	43		48
4			29				27				32	
5		27		31	16	47		57	29	45		47
6			81				92				101	
7		51		42	36	46		47	39	55		102
8			50				49				71	
9				37		17		55	49	79		39
10			52				59				59	
11		49		36	72	57		42	54	62		40
12			57								70	
13	76	86		36	48	92		44	54	110		38
14			103								44	
15		46		53	29	55		68	29	46		52
16			53								59	
17		45		120	53	38			54	48		91
18			115				101				78	
19		54		38	57	62		45	57	83		
20			37				41				60	
21	41	26		32	45	30		50	37	36		38
22			105				50				77	
23		29		43	59	43		57	65	56		45
24			55				76				104	
25	47	62		57		64		64	111	72		21
26			72				84				91	
27	26	79			25	79		23	28	71		29
28			75				94				85	
29	47	38			75	43			48	44		
30			75				78				72	
31		58				49				53		

Table A-5. DAILY TOTAL FLUORIDE CONCENTRATIONS, JUNE 13 THROUGH SEPTEMBER 28, 1970

(ppb)

	Stony River Farm				Steyer No. 2 Farm				Weise-McDonald Farm			
Day	June	July	August	September	June	July	August	September	June	July	August	September
1		0.15		0.06	0.05	0.14		0.05	0.09	0.39		0.11
2			0.06				0.12				0.18	
3				0.05	0.05	0.04		0.07	0.07	0.16		0.06
4			0.03				0.05					
5		0.08		0.05	0.01	0.07		0.08		0.20		0.05
6			0.06				0.07				0.06	
7		0.08		0.10	0.07	0.15		0.06	0.13	0.13		0.14
8			0.04				0.04				0.04	
9		0.07		0.05	0.07	0.06		0.07	0.10	0.11		0.02
10			0.06				0.05				0.04	
11		0.04		0.06	0.06	0.33		0.06	0.10	0.20		0.08
12			0.06								0.05	
13	0.08	0.06		0.04	0.07	0.08			0.06	0.09		0.02
14			0.09								0.05	
15	0.05	0.07		0.05		0.04		0.05	0.08	0.05		0.08
16			0.05								0.05	
17	0.03	0.05		0.11	0.07	0.05		0.05	0.02	0.05		0.07
18			0.09				0.10				0.05	
19		0.05		0.05	0.06	0.05		0.07	0.07	0.06		0.08
20			0.05				0.03				0.07	
21	0.07	0.04		0.04	0.06	0.05		0.05	0.06	0.05		0.06
22			0.05				0.05				0.04	
23	0.07	0.04		0.05	0.06	0.05		0.05		0.05		0.08
24			0.07				0.10				0.08	
25		0.09		0.05	0.12	0.10		0.06	0.12	0.07		0.10
26			0.06								0.05	
27	0.07	0.08			0.13	0.10		0.04	0.03	0.06		0.09
28			0.11				0.09				0.08	
29	0.06	0.04				0.10				0.06		
30			0.07				0.07				0.06	
31		0.06				0.07				0.07		

Table A-6. FLUORIDATION NETWORK RESULTS

Sampling station[a]	Fluoridation rate, ng F/cm^2-day				
	June	July	August	September	Arithmetic mean
401	22	5	12	15	12
402	20	7	12	4	10
403	10	5	12	6	8
404	15	6	-	-	10
405	9	15	3	-	10
406	11	19	22	14	17
407	8	12	11	8	10
409	47	36	30	39	38
410	12	10	13	6	11
411	8	7	12	6	8
412	-	7	13	14	11
413	42	15	28	31	29
414	14	10	14	13	13
415	17	14	14	6	13
416	9	3	3	5	5
417	15	7	8	-	10
418	7	11	14	9	10
419	-	3	-	-	3
421	4	4	5	6	5
422	4	3	-	-	3
423	40	81	37	-	56
424	13	10	12	9	11
425	25	-	-	14	21
426	22	-	-	11	18
427	-	3	-	9	6
428	14	5	13	8	10
429	19	8	10	7	12
430	9	3	8	4	6
431	13	9	10	11	11
432	3	8	6	6	6
433	15	6	10	10	10
434	12	6	19	12	12
435	4	3	6	3	4
436	4	3	6	4	4
437	15	8	5	13	11

Table A-6 (continued). FLUORIDATION NETWORK RESULTS

Sampling station[a]	Fluoridation rate, ng F/cm^2-day				
	June	July	August	September	Arithmetic mean
438	4	3	3	3	3
439	6	5	8	6	6
440	17	8	13	9	12
442	13	6	6	4	8
443	16	8	8	9	10
444	9	5	9	10	8
446	11	10	7	8	10
447	6	4	4	3	4
448	21	14	17	9	15
449	9	7	10	9	8
450	-	-	-	14	14
451	-	7	-	-	7
452	-	11	15	14	13
453	-	8	10	6	8
454	-	-	-	6	6
455	-	-	5	-	5
456	-	-	13	12	13
457	-	-	10	-	10
458	-	9	-	7	7
460	-	-	21	51	31
461	-	-	16	30	20
462	-	-	7	-	7
463	-	-	10	6	8
464	-	-	18	14	16

[a] Index to station locations given in Table A-1.

APPENDIX B.

MT. STORM POWER STATION DATA

Table B-1. MT. STORM POWER PLANT EQUIPMENT DATA

Equipment data	Existing units	Planned unit
Boilers		
Year installed	Unit 1—1965; Unit 2—1966	
Manufacturer	Combustion engineering	
Fuel used	Pulverized coal	
Firing method	Corner-fired	
Rated pressure, psig	2,620	
Rated steam temperature,°F	1,000	
Rated steam capacity, lb/hr	3,785,000	
Flyash collectors and stacks		
Collector type	ESP	ESP
Year installed	Unit 1—1965; Unit 2—1966	1973
Manufacturer	Koppers	Koppers
Design efficiency, %	96	99
Collecting surface area, ft^2	184,320	392,000
Gas flow, acfm	1,820,000	2,230,000
Gas temperature, °F	285	285
Stack height, ft	350	
Stack size (ID), at exit, ft	21	

Table B-2. MONTHLY POWER GENERATION FROM COAL AND COAL CONSUMPTION FOR MT. STORM POWER PLANT

Month	1967		1968		1969	
	Electricity generated, 10^3 kw-hr	Coal burned, tons	Electricity generated, 10^3 kw-hr	Coal burned, tons	Electricity generated, 10^3 kw-hr	Coal burned, tons
1	509,686	218,326	715,470	302,026	DI[a]	246,359
2	289,057	120,214	574,470	236,640	DI	243,262
3	347,534	147,161	702,532	290,625	680,555	276,092
4	295,669	120,466	579,649	246,427	692,413	279,324
5	320,425	135,413	575,751	235,536	732,995	301,130
6	375,297	151,476	601,041	244,497	641,810	263,240
7	624,925	266,382	530,597	213,606	471,750	190,401
8	612,350	254,787	571,685	234,876	253,871	100,584
9	589,655	232,823	510,856	214,746	337,079	137,580
10	388,956	154,839	201,798	83,695	352,662	139,097
11	381,149	150,262	309,767	131,200	467,475	188,945
12	598,437	246,261	457,511	182,505	720,682	290,519
Total	5,333,140	2,198,410	6,331,177	2,617,379		2,656,533

[a] DI - Data incomplete.

Table B-3. MT. STORM POWER PLANT COAL INFORMATION FOR 1970

Month	Coal sulfur content, %	Coal consumed/ month, tons
Jan.	2.25	260,755
Feb.	2.30	179,929
Mar.	2.38	129,773
Apr.	2.49	174,075
May	2.60	211,797
June	2.67	263,428
July	2.65	258,150
Aug.	2.71	241,968
Sept.	2.71	216,118
Oct.	2.56	204,604
Nov.	2.49	171,719
Dec.	2.19	210,895

BLANK PAGE

APPENDIX C.
SPECIAL METEOROLOGICAL STUDIES

POTOMAC RIVER VALLEY AIRFLOW STUDY

In mountain valleys, local wind patterns may dominate the flow. This phenomenon has been investigated by Davidson* and others. Briefly, when the general airflow is light and the skies nearly clear, an up-slope flow tends to develop after sunrise on the sunny slopes as the heated air rises. Later in the forenoon, the flow matures as an up-valley breeze, reaching its maximum strength in the afternoon. In the evening, surface temperatures fall and a down-valley flow develops and persists through the night.

If this flow pattern occurs and persists for several hours in the valley at Luke, Maryland, it can potentially carry Westvaco Plant emissions up-valley to Steyer No. 2 Farm, a distance of 20 miles by river. In order to measure the incidence of this flow, two wind systems were operated on the valley floor at Potomac Manor, West Virginia, during the 1970 study period. Sites, indicated in Figure 1-18, were selected in two segments of the valley nearly perpendicular to each other. It was assumed that when a persistent up-valley wind was recorded at both sites, the wind was up-valley between Westvaco and Steyer No. 2 Farm.

Site No. 20 on Mr. L. E. Murphy's farm utilized a 45-foot mast in order to reach above treetops along the adjacent Potomac River. It supported the wind sensors at 1,640 feet above MSL in a section of the valley where a wind from 105 degrees was considered an up-valley wind. This site is 2-1/2 miles directly east-northeast from Steyer No. 2 Farm and is surrounded by hills reaching more than 2,400 feet above MSL.

Site No. 22 utilized a 32-foot mast and was adjacent to the Western Maryland Railroad on Mr. H. Stewart's property. Wind sensors were at 1,635 feet above MSL where the up-valley wind would flow from the northeast. The site is up-river and around a bend from site No. 20.

Up-valley winds between June 9 and September 29 were determined by comparing 2,671 pairs of hourly average directions from the two valley stations. In those

---

*Davidson, Ben. Valley Wind Phenomena and Air Pollution Problems. APCA Journal 11(8):364-368, 1961.

PRECEDING PAGE BLANK

cases where uninterrupted up-valley flow continued for at least 5 hours, pollutants from Luke could have traveled at least as far as Steyer No. 2 Farm. Ten cases identified as sustained up-valley flow were studied in relation to SO_2 levels and winds at the Steyer Farm station. In nine of these up-valley cases, Steyer Farm station indicated an easterly wind. In five cases, SO_2 1-hour values between 0.01 and 0.05 ppm were recorded, while in four cases no detectable SO_2 was recorded. The data show that up-valley flow is not a significant factor in the transport of pollutants over distances of more than 20 miles in this valley.

AERIAL AND GROUND (MOBILE) SO_2 SAMPLING

A helicopter equipped to measure temperature, altitude, and SO_2 was flown, as weather permitted, during the period November 18 to 23, 1969, to observe the SO_2 distribution throughout the study region. A vehicle equipped to detect SO_2 (mobile sampling system) was also employed. At the Mt. Storm Post Office, from November 6 to December 12, 1969, winds were recorded by sensors approximately 2,870 feet above MSL on a 30-foot mast. During the helicopter operation, upper winds were measured from a pilot balloon (pibal) station at the Post Office.

The weather was generally favorable for the rapid dispersion of contaminants: wind speeds were above average, the stability of the atmosphere at ridge level and above was neutral (although strong inversions occasionally were found in the valleys), and frequent rain or snow showers occurred. Significant findings were:

1. Sulfur dioxide was detected crossing the North Branch of the Potomac River from West Virginia into Maryland between Steyer Farm and the confluence of the Stony and Potomac Rivers, about 7 miles downwind from the Mt. Storm Power Plant. Above the river, but at the elevation of some of the tree farms, the SO_2 concentration averaged 0.10 ppm for the period between 1426 and 1621 EST, November 18, 1969. The average of the peak concentrations for the nine traverses through the plume was 0.23 ppm.

2. Sulfur dioxide was detected entering Garrett County from the west-northwest along the West Virginia - Maryland border at the point where the Potomac Edison Company transmission line crosses the border. It was also detected crossing into Garrett County at the intersection of the Pennsylvania - Maryland - West Virginia state boundaries. At 500 feet above the surface, SO_2 concentrations averaged 0.05 ppm, with the maximum being 0.10 ppm. The Mt. Storm 500-foot pibal wind was 280° at 8 mph at the time (1030 to 1142 EST, November 21, 1969), so that the source of the contamination had to be other than the Albright or Mt. Storm power plants.

3. The mobile SO_2 sampling system measured a plume crossing U.S. Highway 50, 5.3 miles downwind on a bearing of 165 degrees to the Mt. Storm Power Plant

Table C-1. WIND DIRECTION AND SPEED AT THREE LOCATIONS AND CORRESPONDING SO_2 CONCENTRATION RECORDED AT STONY RIVER FARM AIR MONITORING SITE, SEPTEMBER 12, 1970

Hour, EST	VEPCO plant		Steyer No. 2 Farm		Pittsburgh Airport[a]		Stony River Farm
	Direction, compass	Speed, mph	Direction, degrees	Speed, mph	Direction, degrees	Speed, mph	SO_2 concentration, ppm
00	SSE	7	090	1			0.00
01	SSE	8	090	1	Calm	0	0.00
02	S	10	070	3			0.00
03	S	11	060	3			0.00
04	S	10	070	3	080	5	0.01
05	S	8	070	3			0.01
06	S	9	060	5			0.01
07	S	10	080	5	090	6	0.13
08	S	9	090	4			0.22
09	SSE	10	110	6			0.36
10	SSE	8	140	8	160	12	0.24
11	SE	10	130	10			0.05
12	SE	9	130	1			0.09
13	SSE	11	130	1	180	13	0.19
14	SSE	12	150	3			0.24
15	SSE	10	150	3			0.20
16	SSE	9	160	3	190	9	0.28
17	SSE	10	150	3			0.02
18	S	8	180	5			0.01
19	S	9	200	5	210	6	0.00
20	S	9	250	4			0.00
21	SSW	10	250	6			0.00
22	SSW	7	280	8	140	6	0.00
23	SW	7	280	10			0.00

[a] Greater Pittsburgh Airport weather summary gives wind data at 3-hour intervals.

on November 19, 1969, between 0900 and 1200 EST. During this period, the average winds recorded at the Mt. Storm Post Office were from 163 degrees at 12 mph. The plume, arbitrarily defined as more than 0.01 ppm continuously to the maximum and decreasing to 0.01 ppm of SO_2 again, averaged 0.7 mile in width. Its midpoint shifted 1.3 miles along the highway in an erratic manner during the 3-hour period. A maximum of 0.28 ppm was recorded.

4. During mid-morning of November 20, a "looping" plume was observed to intermittently touch ground on the lee shore of Lake Storm. While the vehicle was parked 1.7 miles from the stacks, a 1/2-hour average concentration of 0.65 ppm SO_2 was recorded that included abrupt increases to as much as 1.75 ppm when the plume impinged momentarily on the vehicle.

5. At about 1600 EST on November 22, a 5-minute average of 0.20 ppm SO_2, with a maximum of 0.23 ppm, was recorded at a point 6.3 miles northeast of the Mt. Storm Power Plant. In the late afternoon, the facing slopes of the mountain became shaded. The plume, which was discernible overhead, was rather abruptly drawn down into the lee of the mountain range, where it assumed a more northerly direction and traveled parallel to the crest for several miles as a discrete grey streak.

6. Even with strong winds above the Allegheny Front, inversions can exist in the sheltered valleys. Such inversions trap and confine effluents from sources within the valleys to the lower few hundred feet. On November 23, 1969, such a situation was observed from the helicopter. The Potomac River Valley between Cumberland, Maryland, and Piedmont, West Virginia, was surveyed, with a side excursion being made up New Creek from Keyser to the junction of U.S. 50 with W. Va. 93. The flight was conducted at 200 feet above ground with periodic vertical ascents flown to establish the top of the valley inversion. Indicated SO_2 at the 200-foot flight level averaged 0.18 ppm SO_2 and the maximum recorded was 0.38 ppm.

   The inversion was characterized by reduced visibility and lower temperatures beneath, while improved visibility, higher temperatures, and pronounced change in wind speed and direction were encountered above. The inversion confined the effluents to the lower 700 feet at Cumberland, to the lower 500 feet in the narrows below Piedmont, and below 200 feet at the junction of Routes 50 and 93.

REVIEW OF SO_2 CONCENTRATION AND WIND PATTERN OCCURRING ON SEPTEMBER 12, 1970

On September 12, 1970, between 0700 and 1600 EST, the hourly SO_2 values recorded at the Stony River Farm air monitoring station averaged 0.22 ppm and reached the study period high of 0.36 ppm with the 0900 reading. A review of the recorder chart (Figure 1-19) shows that the instrument "pegged" continuously at full scale (over 0.48 ppm) for 15 minutes. The chart is characterized by abrupt large changes in the level of SO_2 recorded, which indicates sampling of air with non-uniform pollutant concentrations in which parcels of nearly clean air alternated with parcels containing over 0.40 ppm SO_2. Also during this 9-hour period, NO_x levels at Stony River Farm averaged over 0.02 ppm and reached 0.04 ppm for 2 hours. At the other two monitoring sites, no SO_2 was detected during the entire period. The south-southeast daytime wind apparently carried the plume west of these samplers. During the early morning and evening south-wind periods (Table C-1), however, shallow night-time inversions are believed to have prevented the plume aloft from dispersing downward to the ground-level sampling positions.

A surface-based inversion, 1,000 feet deep, existed over Pittsburgh at 0700 EST with east winds below and south-southeast winds above. A second inversion was also present at 4,800 feet MSL, further restricting vertical mixing. Surface winds recorded at the Greater Pittsburgh Airport (shown in Table C-1) indicate that the surface inversion dissipated by 1000 EST.

A comparison of hourly winds strongly indicates that a surface inversion separated Steyer wind-flow from the higher-level Mt. Storm flow with the Stony Farm being near the top of the lower flow so that only traces of SO_2 were mixed down to the sampler until after 0600 EST when the inversion began a rapid breakup.

After 0800, VEPCO's south wind is seen to shift toward southeast while Steyer's east wind shifts into the south to merge as a daytime south-southeast wind* carrying SO_2 effluent from VEPCO toward Stony.

In summary, on September 12, 1970, plumes from the Mt. Storm Power Plant were trapped in a limited-mixing-depth condition for over 9 hours. Much of this time the Stony site was beneath the plume and was subjected to sulfur dioxide levels as great as 0.36 ppm (hourly average). It appears that at the plume center-line the hourly value was greater than 0.48 ppm. During this episode, the plume apparently passed to the west of monitoring stations at the other two farms so that no sulfur dioxide was recorded by either of them. Prior to 0700 EST and after 1600 EST, the sampler at the Stony River Farm is thought to have been screened from the plume by a shallow surface inversion, the top of which was below the wind sensor at the Mt. Storm plant.

---

*The 1100 and 1200 VEPCO winds show a temporary shift of 2 compass points toward the east. The shift correlates in a striking manner with a temporary drop in SO_2 recorded at Stony.

APPENDIX D.

METEOROLOGICAL DATA

PRECEDING PAGE BLANK

Table D-1. COMPARISON OF FREQUENCY OF WIND DIRECTIONS AT INDICATED STATIONS, JUNE THROUGH SEPTEMBER 1970

Direction	Wind direction at Steyer No. 2 Farm Station,[a] % frequency					Wind direction at Mt. Storm Power Plant Station,[b] % frequency				
	June	July	Aug.	Sept.	Season	June	July	Aug.	Sept.	Season
N	1	1	3	3	2	1	1	1	0	1
NNE	0	0	1	0	0	1	1	1	1	1
NE	2	1	5	1	2	1	1	1	0	1
ENE	2	1	3	2	2	1	0	1	1	1
E	6	7	6	7	7	2	0	3	0	1
ESE	2	1	3	2	2	1	1	2	1	1
SE	3	2	6	2	4	2	6	8	3	4
SSE	1	1	2	1	1	3	3	5	5	4
S	2	2	2	2	2	5	4	5	8	5
SSW	2	3	1	2	2	7	6	7	7	7
SW	7	12	3	5	6	7	7	4	10	7
WSW	23	16	9	14	15	13	12	7	17	12
W	35	34	35	35	35	20	19	16	23	20
WNW	6	10	10	13	10	21	24	20	11	19
NW	5	6	8	9	7	11	10	15	12	12
NNW	3	3	3	2	3	4	5	4	1	4

[a] Operated by APCO on southeast facing slope of Steyer No. 2 Farm on 30-foot tower. Elevation is approximately 2,700 feet above MSL.

[b] Operated by VEPCO on hill west of plant on 88-foot tower. Elevation is approximately 3,500 feet above MSL.

PART TWO

LUKE, MARYLAND – KEYSER, WEST VIRGINIA, INTERSTATE AIR POLLUTION ABATEMENT ACTIVITY AREA

I. SUMMARY AND CONCLUSIONS

A technical investigation of air quality in the Luke, Maryland - Keyser, West Virginia, area was conducted as part of the Mt. Storm, West Virginia - Gorman, Maryland, and Keyser, West Virginia - Luke, Maryland, Air Pollution Abatement Activity. The area was included at the request of the Governor of West Virginia.

The area of study centered around the North Branch of the Potomac River, extending from Bloomington, Maryland, to Keyser, West Virginia, and including the towns of Luke, Westernport, Piedmont, and McCoole.

Pollutant concentrations approached or exceeded levels generally found in industrialized areas, partly because the area's topography and meteorology exert a strong influence on the buildup of pollutants. Particulate matter and sulfur dioxide were the major pollutants, and the maximum levels in the region were found in Luke, Maryland, and Piedmont, West Virginia. Complaints of odors have also been received from residents of Maryland and West Virginia, and as far as Somerset County, Pennsylvania.

A pulp and paper mill operated by the Westvaco Corporation is the primary source of air pollutants. Although the plant is now implementing an air pollution control program, compliance with Maryland regulations will not be achieved until 1975 or 1976. When all the improvements now planned are completed, both the particulate and sulfur oxides emissions should be substantially lower. Odorous emissions (reduced sulfur compounds) should also be lower, although company plans for reduction of these emissions are still incomplete. The 1975 completion date appears unnecessarily extended, however. The control program could be completed sooner by reducing the delay involved in developing the proprietary Westvaco activated-carbon process (for flue-gas desulfurization) as a control alternative.

A number of other small sources contribute to the overall pollution. These include a coal-washing plant, a charcoal plant, and a gob pile (refuse dump), all of which are located in Beryl, West Virginia. Residents of both states have registered some complaints concerning emissions from these sources.

Data for relating air pollutant levels to effects on health, vegetation, and materials in this area are limited. Studies done in other areas with similar air quality, however, indicate possible correlations between pollutant concentrations and respiratory diseases such as emphysema and bronchitis. In this area vegetation damage is plainly visible on the ridge above and south of Piedmont, and evidence of high metal-corrosion rates has been detected.

The conclusions drawn from this study are given below:

1. Interstate transport of air pollutants originating from sources in both Maryland and West Virginia occurs.
2. Industrial emissions create severe, localized air pollution in the river valley with very high hydrogen sulfide and particulate levels occurring. Sulfation-plate measurements indicate sulfur dioxide levels in excess of the recently proposed national air quality standards.[1]
3. The Westvaco pulp and paper mill at Luke, Maryland, is the dominant source of air contaminants. The present Westvaco compliance plan is inadequate because the sulfur oxides control program is unnecessarily long and the total reduced sulfur control program is incomplete.

II. INTRODUCTION

The attention of air pollution officials has been drawn to the upper Potomac River region because of severe air pollution problems in the river valley. At Luke, Maryland, beside the North Branch of the Potomac River, the Westvaco Corporation operates a pulp and paper mill that is the major manufacturing concern of the region, producing approximately 800 tons of pulp daily. This mill is also the dominant contributor to the air pollution that occurs in the region. The balance of the air pollution comes from a number of small industrial sources, including a charcoal plant and a coal-screening operation, both located in Beryl, West Virginia.

The populated area of the region extends from Bloomington, Maryland, to Keyser, West Virginia, along the Potomac River. Westernport is the largest town in the Maryland portion of the area, whereas Keyser contains the majority of the population in the West Virginia portion of the area. Luke and McCoole on the Maryland side of the river, and Piedmont on the West Virginia side, are the other communities in the region defined. The Luke-Keyser valley is remote from other centers of population; its inhabitants are relatively few and are dependent on the continued economic viability of the pulp mill.

HISTORY OF ABATEMENT ACTIVITY

This study, part of the Mt. Storm, West Virginia - Gorman, Maryland, and Keyser, West Virginia - Luke, Maryland, Air Pollution Abatement Activity, was a cooperative effort of the U.S. Environmental Protection Agency and the States of Maryland and West Virginia. Governor Arch A. Moore of West Virginia, in a letter dated February 24, 1970, requested that the Piedmont-Keyser area of West Virginia be included in the abatement action.

DESCRIPTION OF AIR POLLUTION PROBLEM

Basic to the Kraft pulp-producing process is the use of large quantities of fossil fuel and water. The Westvaco mill at Luke uses coal obtained from nearby mines as fuel, and the combustion products formed include both particulate emissions, in the form of flyash, and sulfur oxides.

In the Kraft process for the digestion of wood, both the inorganic chemicals used and the organic compounds derived from the wood pass through a series of reactions in which odorous gases are produced, which are often vented to the atmosphere. A key economic element in the Kraft process is the recovery and reprocessing of the spent chemical in the cooking liquors. The furnaces used in the recovery of the chemicals are an additional source of airborne particulate matter, of sulfur oxides, and especially of odors. The odors are detectable in concentrations so low that they can be smelled even at great distances from the mill.

The pollution burden placed on the atmosphere from particulate and sulfur oxides emissions is, however, more significant from a health standpoint than the odors, even though the effects of the former are not as obvious. Even the copious steam emissions from the pulp mill can be objectionable because they form a persistent fog during cold or humid weather (Figure 2-1).

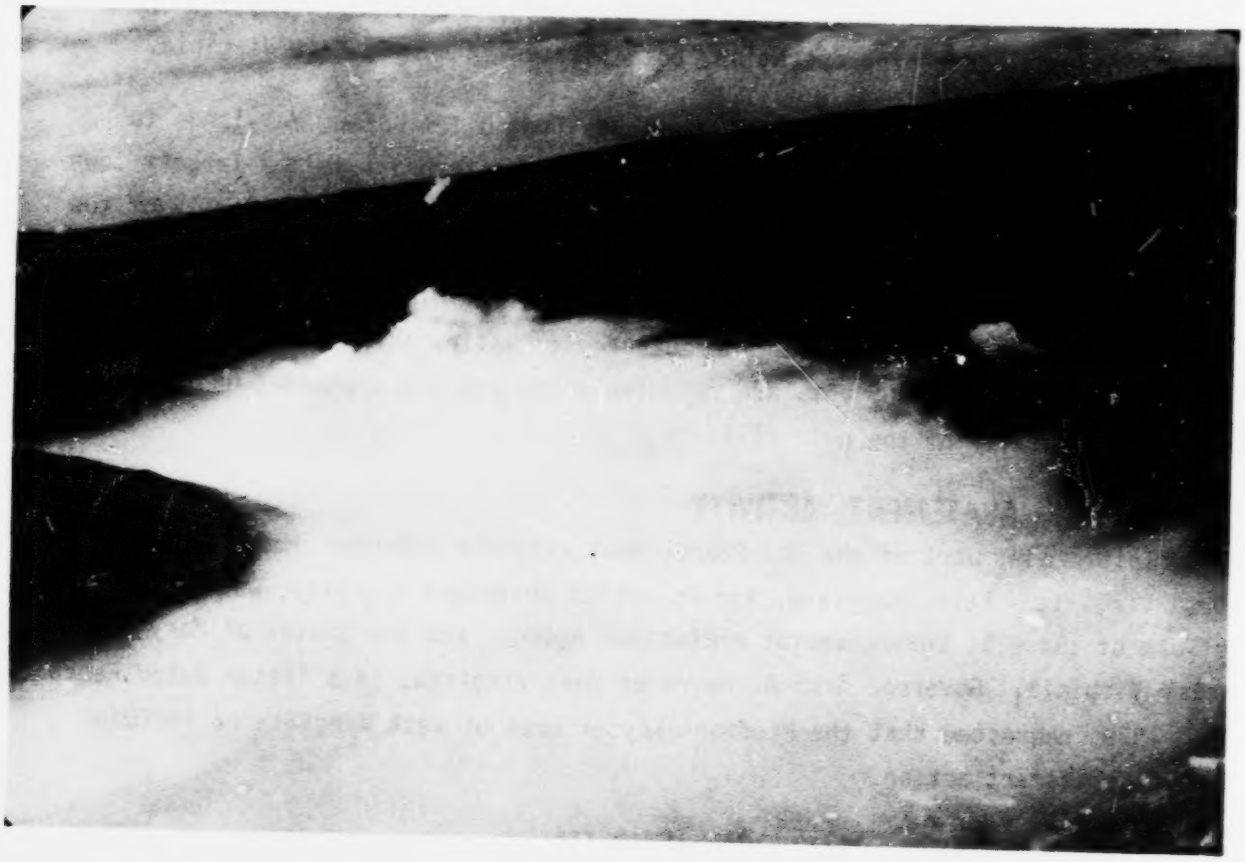


Figure 2-1. Aerial view looking west over Westernport; denuded ridge to left bears brunt of emissions. Plume rising to left center locates the Luke mill.

In this report, the air pollution in the Luke - Keyser area is discussed in terms of the quantitative air quality and the air contaminant emission data, which are summarized. Because it is the dominant emission source, Westvaco is discussed in detail.

III. AREA DESCRIPTION

From Bloomington, Maryland, the North Branch of the Potomac River assumes a southeasterly course as it cuts through the Allegheny Front range to Keyser, West Virginia, where it takes a northeasterly course. The region of the Potomac Valley from Bloomington to Keyser is the subject of this report. A map of the region is shown in Figure 2-2. On the Maryland side of the river, the towns of Bloomington, Luke, and Westernport are spaced a river-mile apart at successive major bends. The Savage River and George's Creek flow into the Potomac from the northeast at Luke and Westernport, respectively. From Piedmont, West Virginia, Westernport is north across the river; Luke is northwest. Because of the winding, narrow character of the Potomac River Valley, all three towns are surrounded, within 1 mile, by elevations more than 1,500 feet above river level. At Piedmont, the river is 900 feet above mean sea level (MSL), and the adjacent mountains reach more than 2,500 feet above MSL. Although the towns extend from the river bank up the sides of the hills, their centers are about 200 feet above the river.

From Westernport, the river flows 5 miles through a narrow valley to a broader area, where McCoole is situated on the Maryland side and Keyser, the largest town in the area, on the West Virginia side. The downstream end of the valley is 20 miles southwest of Cumberland, Maryland.

Joining the Potomac at Westernport is George's Creek, which has been described as the single most unfortunate stream in the Potomac Basin because of the massive doses of mine acid that leach into it from the devastated mining region in the valley beside it.[2] The George's Creek and Savage River valleys are important because they provide alternate troughs for the air currents that carry pollutants from the main valley of the Potomac.

The mountainous terrain and the brevity of the growing season limit agricultural activity in the region. The vegetation of the area includes hardwood and pines that grow on the mountain slopes overlooking the river valleys.

The total population of the region is about 12,000, more than one-half of which live in Keyser. Table 2-1 summarizes the known population levels by county.

During the past 10 years, Piedmont, Westernport, and Luke have experienced a decline in population, in contrast to the national trend. This decline has been particularly severe at Piedmont, which has lost 23 percent of its total 1960 population.

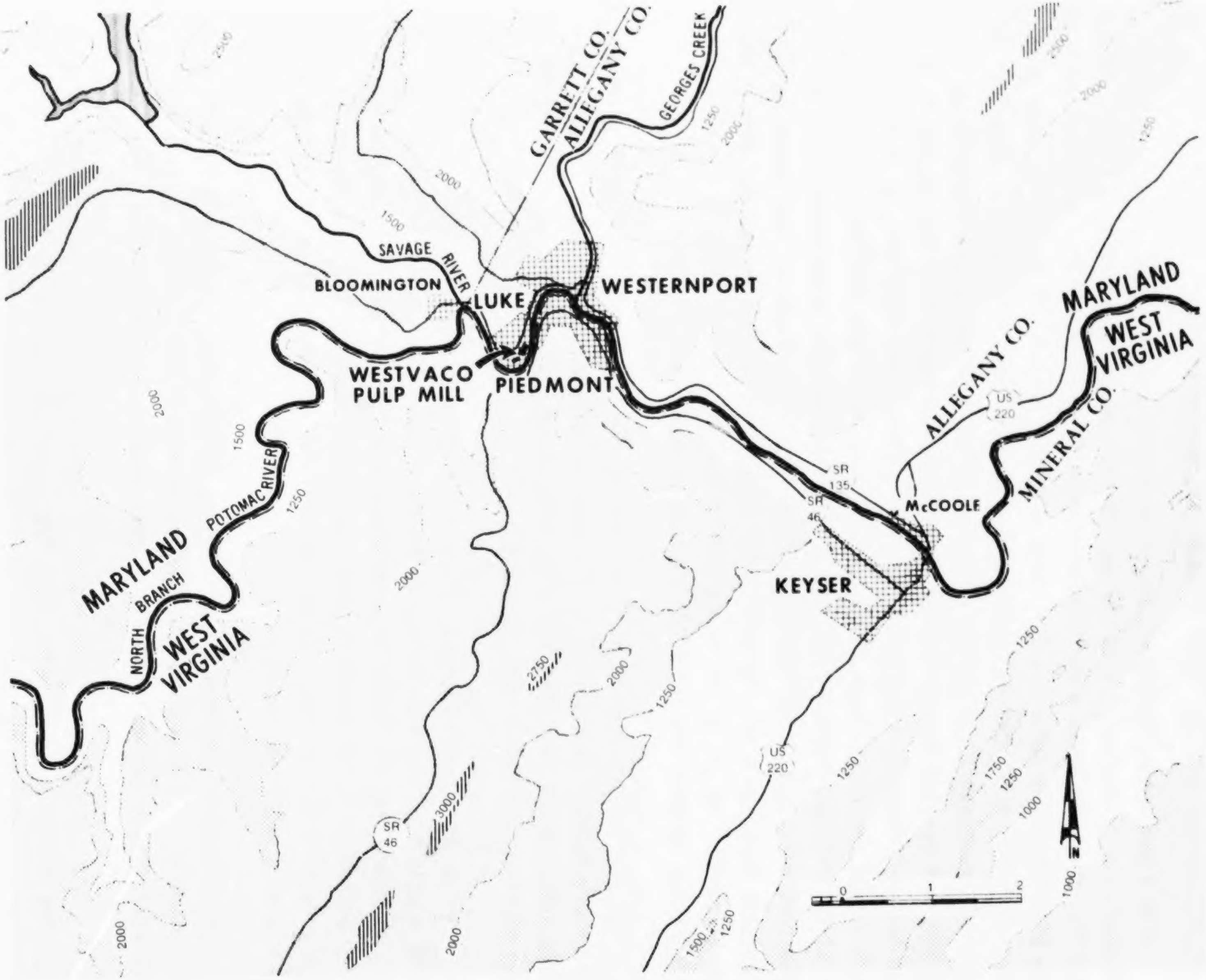

GARRETT CO.
ALLEGANY CO.
GEORGES CREEK
SAVAGE
RIVER
BLOOMINGTON
LUKE
WESTERNPORT
WESTVACO
PULP MILL
PIEDMONT
MARYLAND
WEST
VIRGINIA
ALLEGANY CO.
MINERAL CO.
US
220
SR
135
SR
46
McCOOLE
KEYSER
POTOMAC RIVER
NORTH
BRANCH
MARYLAND
WEST
VIRGINIA
2500
2000
1500
1250
2750
3000
1750
1000
0
1
2
N

Figure 2-2. Topography of Luke-Keyser area.

Table 2-1. POPULATION OF LUKE-KEYSER REGION

County	1960[3]	1970[a]
Garrett County, Maryland	20,420	21,476
Bloomington[b]		
Allegany County, Maryland	84,169	84,044
Luke	587	424
Westernport	3,559	3,106
McCoole[b]		
Mineral County, West Virginia	22,354	23,109
Keyser	6,192	6,586
Piedmont	2,307	1,763
Beryl[b]		

[a] Preliminary data.[4]

[b] Not tabulated in census.

The climate is temperate, Westernport temperatures ranging from an average of 74° F in July to an average of 34° F in January. Located on the lee side of the Allegheny Mountains, the Luke-Keyser region enjoys warmer temperatures and less precipitation than the western slopes of the mountains (Table 2-2).

Table 2-2. PRECIPITATION AND TEMPERATURE IN WESTERNPORT, 1968[5]

Indicator	Mean
Total annual precipitation, inches	38.86
Number of days with 0.10 inch or more rain	81
Daily maximum temperature, °F	65.7
Daily minimum temperature, °F	42.0

Airflow in the region is not affected by the prevailing weather patterns as much as by topography. Deep within the valleys and close to the sloping side-walls, the airflow is usually determined by local, constantly changing factors. A down-slope wind tends to develop slowly into a down-valley wind in the evening; the latter persists through the night and dissipates rapidly after sunrise, except under heavy cloud cover or exceptionally strong and turbulent wind conditions. Daytime winds are less consistent, but tend to blow toward the nearest heated slope. During the 1970 growing season, up-valley winds were recorded only 7 percent of the time, whereas down-valley winds occurred 57 percent of the time. Variable, cross-valley winds and calm accounted for the remaining 36 percent of the time. These measurements were obtained in the Potomac River airflow study reported in Part One, Appendix C.

Average wind speeds are low, and calm periods, which tend to increase pollutant concentrations, are frequent. In general, when air temperature decreases with increasing height, the air is unstable and vertical mixing occurs. When the ground is relatively cool and temperature increases with height, the air is stable, little vertical mixing occurs, and, in meteorological terminology, an inversion is said to exist. In the Luke-Keyser region, inversion conditions exist 30 percent of the time at exposed locations, with significantly greater frequency in valley areas.

In addition, high-pressure weather patterns moving from west to east across the country occasionally settle over the eastern states, particularly during autumn, and remain stable for days. The result is an atmospheric stagnation period with light winds and a resulting accumulation of pollutants. In the Luke-Keyser region, stagnation periods lasting 4 days or longer may be expected at least once a year.

IV. WESTVACO PULP AND PAPER MILL

PLANT OPERATIONS

In the following sections, the power boilers and the pulp-making processes are considered separately. The odors characteristic of Kraft pulp mills come primarily from the chemical recovery system included in the pulp-making section. Most of the sulfur oxides originate in the power boilers from the burning of sulfur-containing fuels. Smaller quantities come from the recovery furnaces. Both the power boilers and the pulp-making processes are responsible for the particulate emissions.

Pulp-Making Processes

The necessity for producing a highly uniform product, pulp, from a highly variable raw material, such as trees, requires a complex and well-controlled process. The Kraft process as employed at Luke results in a relatively strong fiber. It requires cooking wood chips in large pressure cookers, called digesters, until the cellulose fibers, the pulp, are completely separated from the lignins, which are the nonfibrous constituents of wood. To accomplish this separation, it is necessary to react lye (sodium hydroxide) and sodium sulfide with the lignins. After it is separated, the pulp is removed from the cooking liquor and washed.

A key economic feature of the Kraft process is the recovery of the chemicals used in the digesters. This involves concentration of the spent cooking liquor by evaporating the water and then burning the concentrated black liquor in a recovery furnace to separate the sodium-based inorganic materials from the reacted lignins. The inorganic smelt from the recovery furnace consists of sodium sulfide and sodium carbonate. The smelt is dissolved in water and then reacted with lime to convert the carbonate to sodium hydroxide. The resulting sodium sulfide-sodium hydroxide solution is then recycled to the digester where it is reused as cooking liquor. The calcium carbonate also produced in this last reaction is calcined to lime in the lime kiln.

This chain of digestion, evaporation, and recovery has associated with it a large variety of chemical compounds, some of which have strong odors. The principal malodorous gases emitted are sulfur compounds, listed in Table 2-3. Collectively, these odorous sulfur emissions are usually referred to as total reduced sulfur (TRS) compounds. The formation of most of them can be reduced significantly by the application of currently available technology.

Table 2-3. PRINCIPAL MALODOROUS GASES FROM KRAFT PROCESS[6]

Gas	Formula	Odor threshold, ppm
Hydrogen sulfide	H_2S	0.1
Methyl mercaptan	CH_3SH	0.01
Dimethyl sulfide	CH_3SCH_3	0.05
Dimethyl disulfide	CH_3SSCH_3	0.50

Digesters - The Luke mill has nine digesters, three for softwood and six for hardwood. Depending on the cooking time, these usually produce 800 tons of air-dried pulp per day - 300 tons from softwood and 500 from hardwood. A batch of chips in white liquor will usually reach the 350° F cooking temperature in about 1-1/2 hours. The digester is held at this temperature for 1 to 3 hours at a pressure of about 100 pounds per square inch (psi).

To maintain the temperature and pressure while gases are being generated, the digester requires constant venting through relief valves. Two small cyclones are used in the vent lines to remove entrained particulate matter and condensable gases. Mercaptans and hydrogen sulfide, however, are emitted in variable quantities, depending on the type of wood, the sulfide concentration in the liquor, the cooking temperature, and the length of the cook.

When cooking is complete, the pulp and black liquor are violently discharged from the digester into a blow tank. At Luke, 56 to 63 digester blows are made each day.[7] The TRS emissions from both the blow and the digester relief vent are major contributors to the mill's odor problem. Because their volume is small, however, the off-gases could be vented to the lime kiln or the recovery furnace for incineration. Incineration in the lime kiln is preferred because the SO_2 from combustion would be considerably less because it is reduced by the alkaline scrubbing medium used in the kiln scrubber.

Knotter and Brown Stock Washers - From the blow tank, the pulp and black liquor are pumped through the knotter to screen out the undigested material and into the brown stock washer, where the pulp is separated from the black liquor. Significant quantities of TRS compounds can be emitted from the hood vents on the washer, particularly if untreated condensates are being used in it. A variety of techniques are available for controlling odorous emissions from these processes, such as venting the gases to the recovery furnace for incineration.

Multiple-Effect Evaporators - Multiple-effect evaporators are used to reduce the water content of the black liquor as it comes from the brown stock washers. The liquor is passed through several heated vacuum stages, in which the heat source for one stage is the evaporant from the succeeding stage. Vacuum is maintained by barometric condensers. This process results in efficient utilization of the thermal energy and reduces the water content from 87 to about 50 percent by weight. Luke has two lines of multiple-effect evaporators.

The evaporated vapors are condensed and passed to a hot well. The quantity of water required for condensation is about 1,000 gallons per minute. Condensed black liquor is rich in malodorous sulfur compounds, and the odors may persist if the liquor is discharged into the river untreated. A relatively high degree of odor control can be achieved by steam stripping the condensate from the digester and the multiple-effects evaporators to remove volatile compounds. The off-gases from the condensate stripper must also be treated, by incineration, to prevent odorous emissions. The same is true for the condensate; it must be treated prior to discharge, or recycled within the plant. Odorous TRS compounds are also present in the noncondensable gases from the evaporator. The small amount of effluent gas produced by the evaporator could be shunted and effectively eliminated by incineration.

Direct-Contact Evaporator, Recovery Furnaces - The direct-contact evaporator and the multiple-effect evaporators are the primary sources of the steam emissions. At Luke, the black liquor is concentrated to 50 percent solids in the multiple-effects evaporators and is then sent to the strong-black-liquor-oxidation system that was installed recently. Here, its sodium sulfide content is oxidized to sodium thiosulfate by contacting the liquor with air. Complete oxidation is required, however, in order to decrease TRS emissions effectively. In many cases, complete oxidation is difficult to achieve and the black-liquor-oxidation tower can itself become an additional source of TRS emissions. Effective oxidation prevents excessive hydrogen sulfide emission when the liquor is brought into contact with the recovery-furnace exhaust in the direct-contact evaporator.

In the recovery furnace, the organic material dissolved from the wood (about half the original dry weight) is burned, the residual sodium hydroxide is converted to sodium carbonate, and any oxidized sulfur compounds are reduced to sodium sulfide. Inorganic salts accumulate in the bottom of the furnace as a molten smelt. The steam produced here, from the combustion of the lignin, is piped throughout the mill for use in other stages.

Hot flue gases from the recovery furnace also contain steam, along with gaseous sulfur compounds, solid particulate matter, and carbon dioxide. These pass through an electrostatic precipitator before being discharged to the atmosphere.

Luke has two recovery furnaces, each equipped with an electrostatic precipitator (Figure 2-3). The recovery furnaces together emit an estimated 250 to 300 tons

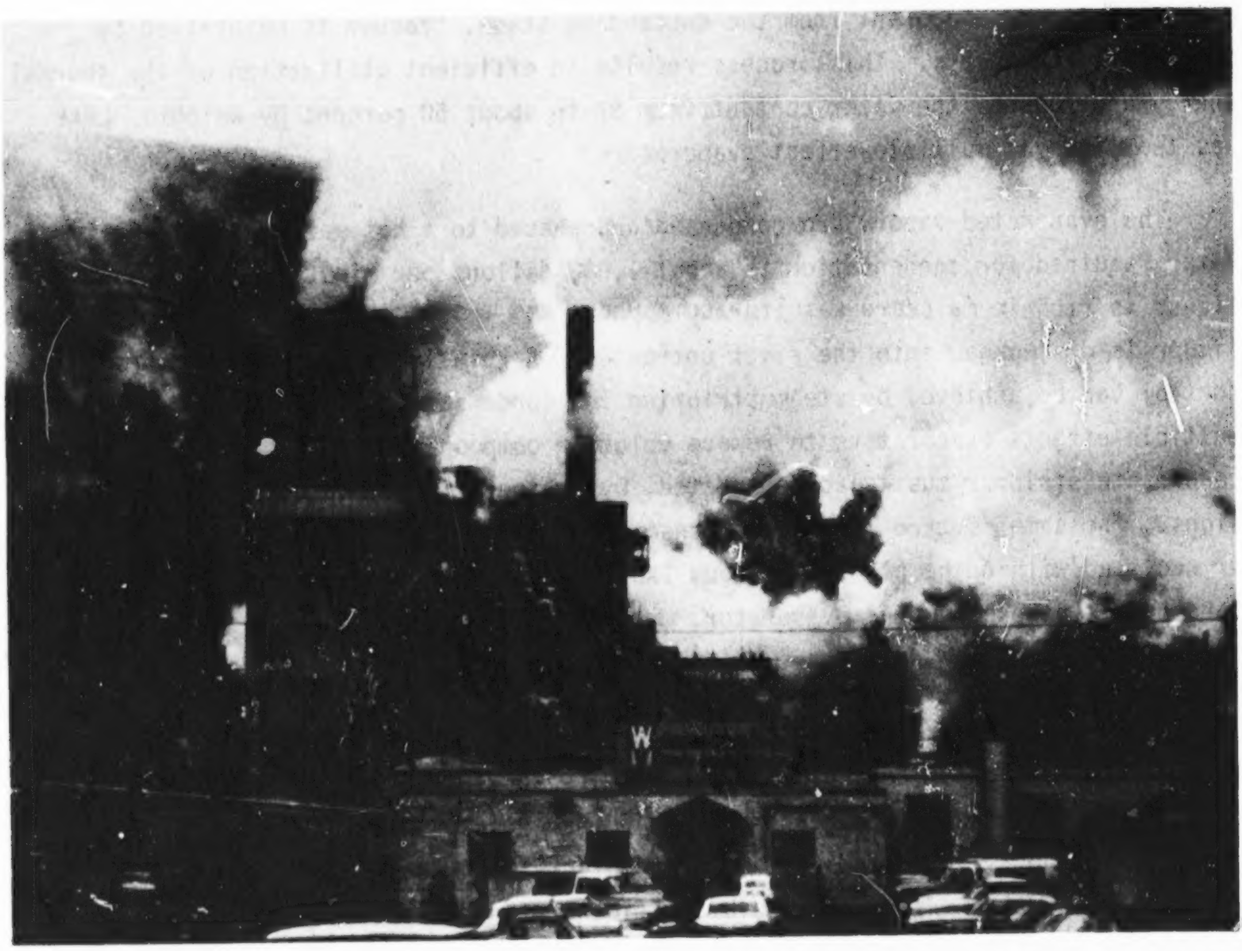


Figure 2-3. View of Luke mill showing electrostatic precipitators to left of stack.

of sulfur dioxide per year and 2,300 tons of particulate matter per year.[8] The recovery furnaces operate with excess oxygen and thus minimize the emissions of odor-causing sulfur compounds by oxidation.

Smelt Tanks - The inorganic smelt, consisting of sodium carbonate and sodium sulfide, is discharged into smelt tanks, where it is dissolved in water to produce what is called "green liquor." When it is taken from the recovery furnace, the smelt, at a temperature of approximately 1,500°F, produces steam along with alkali fumes when mixed with water. At the time of this study, one smelt tank at Luke was being equipped with a demister designed to minimize direct discharge of these fumes. The other tank was directly vented to the atmosphere. A second demister or a scrubbing device on that tank could produce a significant reduction in alkaline particulate emissions.

Lime Kiln - Green liquor is changed into white liquor, ready for reuse in the digesters, by converting its sodium carbonate to sodium hydroxide. This is accomplished by caustisizing it with lime (calcium oxide). In solution, calcium oxide becomes calcium hydroxide and reacts with the liquor to give sodium hydroxide and calcium carbonate. The calcium carbonate is collected and returned to the lime kiln, located across the river in Piedmont, West Virginia. There it is heated to about 1,500°F, at which it decomposes to give carbon dioxide and calcium oxide.

The Luke lime kiln is equipped with a wet scrubber for eliminating the particulate matter entrained in the flue gas. The scrubber is reported to be 99.5 percent efficient,[8] releasing approximately 18 pounds of emissions per hour (80 tons per year). Significant quantities of TRS compounds can be emitted from the lime kiln, however, as a result of incomplete washing of the calcium carbonate mud, or the use of untreated evaporator or digester condensate in the scrubber, or as a result of not maintaining proper kiln temperature. All of these are controllable, and careful kiln and scrubber operation and proper washing can eliminate most of the odor from the lime kiln.

Power Boilers

Fuel usage at the Luke mill corresponds to that of a steam electric-power-generation plant with a capacity in excess of 100 megawatts. In the past, the four power boilers have been operated without even the simplest type of air pollution control equipment, although mechanical collectors have been available at a minimal cost for well over 50 years. Such collectors would have reduced particulate emissions 50 to 75 percent. Westvaco has now equipped boiler No. 25 with collectors and a moderately efficient electrostatic precipitator. Boilers No. 22, No. 23, and No. 24 remain uncontrolled, however.

The four original boilers and the new boiler installed recently are described below:

No. 22. An auxiliary, pulverized-coal-fired boiler presently used for standby service; it has no emission controls.

No. 23. An auxiliary, pulverized-coal-fired boiler also used for standby service; it has no emission controls.

No. 24. A cyclone, coal-fired boiler; it has no fly-ash controls and uses around 165,000 tons of coal per year.

No. 25. A large, pulverized-coal-fired boiler equipped with mechanical collectors and an electrostatic precipitator, which has recently been upgraded to approximately 95 percent efficiency. This boiler uses 200,000 tons of coal per year.

No. 26. A new oil-fired boiler, using No. 6 oil that contains 1 percent sulfur; this was installed during February 1970 and this boiler complies with Maryland regulations.

Summary

Data from 1970[7] show total plant emissions of 6,414 tons of particulate matter per year, 21,467 tons of sulfur oxides per year, and 1,713 tons of reduced sulfur compounds per year. In Table 2-4 these emission rates are listed for each of the major processes in the mill. Boiler No. 24 is the primary source of particulate matter. Boiler No. 25 complies with Maryland regulations for particulate emissions, but is the largest emitter of sulfur oxides. The recovery furnaces and the digesters are the main sources of the odorous reduced-sulfur compounds.

Table 2-4. PLANT EMISSIONS, 1970[7]
(tons/yr)

Equipment	Particulate matter	Sulfur oxides	Reduced sulfur
Boilers			
No. 22	Standby	Standby	Neg[a]
No. 23	Standby	Standby	Neg
No. 24	2,624	7,966	Neg
No. 25	903	11,953	Neg
No. 26	80	1,272	Neg
Recovery furnaces			
No. 1	788	188	280
No. 2	1,545	88	700
Smelt tanks	394	Neg	36
Digesters	Neg	Neg	652
Multiple-effect evaporators	Neg	Neg	45
Lime kiln	80	ND[b]	ND
Plant total	6,414	21,467	1,713

[a] Negligible.

[b] No data available.

CONTROL PROGRAM AND COMPLIANCE SCHEDULE

Emissions from Westvaco's Luke mill consist mainly of particulate matter, sulfur oxides, and reduced sulfur compounds. Air contaminant emission rates are presently greater than allowed under Maryland Regulation 43P02.[9] Accordingly, Westvaco submitted a compliance plan (included in the Appendix), dated June 25, 1970, that has been accepted by the Maryland Department of Health and Mental Hygiene. In the sections below, the compliance plan is examined as it pertains to each of the pollutant types. Emphasis is placed on the degree of control needed and the time period required to achieve it.

Table 2-5. PARTICULATE EMISSIONS
(tons/yr)

Equipment	1969	1973	1975-76
Boilers			
No. 22	1,199	Standby	NA[a]
No. 23	359	Standby	NA
No. 24	2,624	2,624	245
No. 25	903	903	692
No. 26	NA	80	80
Recovery furnaces			
No. 1	788	Standby	NA
No. 2	1,545	Standby	NA
No. 3	NA	288	288
Smelt tanks			
No. 1	197	197	197
No. 2	197[b]	86	86
Lime kiln	80	80	80
Total	7,892	4,258	1,668

[a] NA - Not applicable.
[b] Estimate.

Control of Particulate Emissions

Control of particulate emissions will be accomplished in essentially two stages (Table 2-5). The first stage of particulate reduction will be completed in 1972, but the second will not be finished until 1975 or 1976. The second stage is an integral part of the sulfur oxides control program and will be discussed in a later section.

One of the improvements included in the first step has already been completed on schedule. This is the new 240,000 pounds-per-hour packaged-steam boiler (No. 26), which has an emission rate of 0.055 pound of particulate matter per million Btu input. This unit replaced boilers No. 22 and No. 23, which have emission rates of 7.5 pounds per million Btu input each. Boilers No. 22 and No. 23 have been placed on emergency standby. The installation of No. 26 has resulted in an overall particulate reduction of 1,500 tons per year.

A new black-liquor recovery furnace (No. 3) will be installed and in operation by November 1972. It will replace furnaces No. 1 and No. 2, which will also be placed on emergency standby. The new furnace will be oversized (1,000-ton-per-day capacity handling a 750- to 800-ton-per-day load) in order to ensure efficient combustion. With the additional help of an electrostatic precipitator with 99.5 percent efficiency, No. 3 is expected to reduce emissions to 2,000 tons per year.

The anticipated overall reduction in particulate emissions upon completion of all the step-one improvements will be 3,500 tons per year, or almost 50 percent of the original total. The time involved in completing these changes is considered reasonable.

Control Of Sulfur Oxides Emissions

Boilers No. 24 and No. 25 are, by far, the major sources of sulfur oxides emissions (Table 2-6), but Westvaco has not yet chosen an approach for reducing sulfur oxides emissions. The control alternatives listed in the compliance plan include the use of the Westvaco activated-carbon process for flue-gas desulfurization, the use of low-sulfur coal, and the use of low-sulfur oil. The decision presently hinges on the results of developmental work being done on the Westvaco activated-carbon process.

Table 2-6. SULFUR DIOXIDE EMISSIONS
(tons/yr)

Equipment	1969	1973	1975-76
Boilers			
No. 22	456	Standby	NA[a]
No. 23	456	Standby	NA
No. 24	7,966	7,966	940
No. 25	11,953	11,953	1,399
No. 26	NA	1,272	1,272
Recovery furnaces			
No. 1	188	Standby	NA
No. 2	88	Standby	NA
No. 3	NA	0	0
Lime kiln	ND[b]	ND	ND
Total	21,107	21,191	3,611

[a] NA - Not applicable.

[b] ND - No data available.

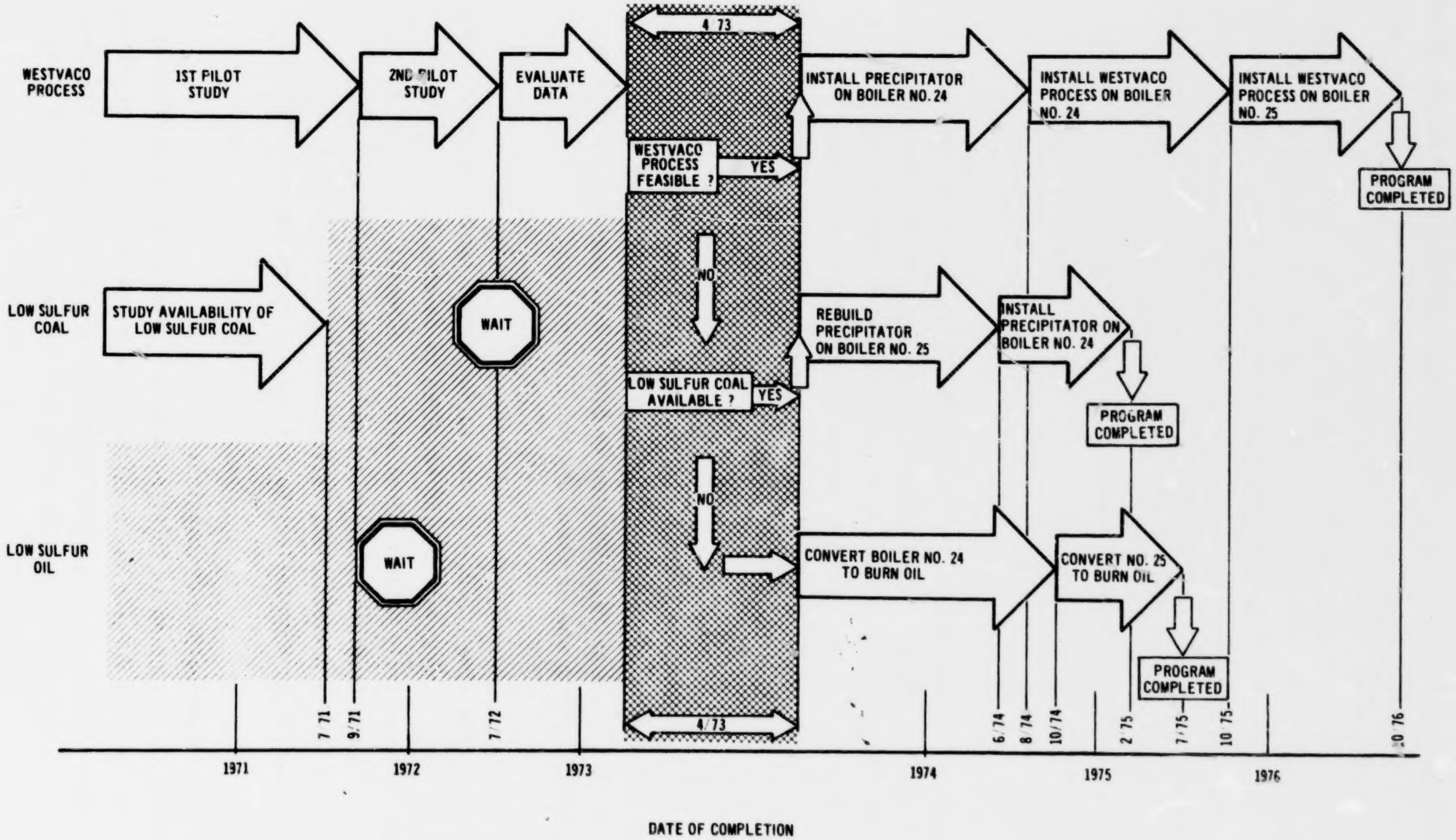

WESTVACO PROCESS
LOW SULFUR COAL
LOW SULFUR OIL
1ST PILOT STUDY
2ND PILOT STUDY
EVALUATE DATA
4/73
WESTVACO PROCESS FEASIBLE ?
YES
NO
INSTALL PRECIPITATOR ON BOILER NO. 24
INSTALL WESTVACO PROCESS ON BOILER NO. 24
INSTALL WESTVACO PROCESS ON BOILER NO. 25
PROGRAM COMPLETED
STUDY AVAILABILITY OF LOW SULFUR COAL
WAIT
LOW SULFUR COAL AVAILABLE ?
YES
NO
REBUILD PRECIPITATOR ON BOILER NO. 25
INSTALL PRECIPITATOR ON BOILER NO. 24
PROGRAM COMPLETED
WAIT
CONVERT BOILER NO. 24 TO BURN OIL
CONVERT NO. 25 TO BURN OIL
PROGRAM COMPLETED
4/73
7/71
9/71
7/72
6/74
8/74
10/74
2/75
7/75
10/75
10/76
1971
1972
1973
1974
1975
1976
DATE OF COMPLETION

Figure 2-4. Flow chart of sulfur dioxide control program at Westvaco Mill in Luke, Maryland.

One important deficiency in the sulfur oxides control program as presented in the company compliance schedule is that the entire control program will be delayed 2 years while the company does developmental work on the Westvaco process, which is a proprietary process. The delay appears unnecessary because SO_2 control systems that could be applied are presently in the advanced pilot stage or prototype stage of development. An SO_2 control system such as sodium carbonate scrubbing should be particularly attractive since the soluble sulfur compounds produced could be recycled to the recovery system. Since the company does not plan to make the basic decision on what approach to take until April 1973, the sulfur oxides problem at the Luke plant will not even be considered per se until then. In addition, up to 3-1/2 years more will be required for installing the necessary equipment (Figure 2-4).

The delay built into the sulfur oxides control program also affects the particulate control program. After completion of the step-one improvements in November 1972, boilers 24 and 25 will be, by far, the predominant particulate sources. The nature of the controls necessary for these units cannot be determined, however, until the sulfur oxides control approach is chosen. Controls for these units will thus be delayed 2 years.

As the company schedule indicates, data from the first Westvaco Process pilot plant study and results of the low-sulfur-coal availability study would be ready by September 1971. The delay, indicated in Figure 2-4, could be avoided by proceeding directly with one of these control alternatives.

In summary, the time schedule of the sulfur oxides control program appears unnecessarily long. The 2-year period required to develop the proprietary process will unnecessarily delay control efforts, especially since other control techniques will undoubtedly be available before that time. Without sacrificing the flexibility of its present plan, Westvaco should be capable of controlling sulfur oxides emissions from boilers No. 24 and No. 25 by the end of 1973.

Control of Total Reduced-Sulfur Emissions

A significant reduction in total reduced-sulfur emissions should occur after the new recovery furnace is installed in 1972 (Table 2-7). With the good combustion conditions expected in this unit, most of the reduced-sulfur compounds will be oxidized to the much less obnoxious form of sulfur dioxide (increasing SO_2 emissions less than 2 percent). The recovery furnaces are presently

Table 2-7. TOTAL REDUCED-SULFUR EMISSIONS
(tons/yr)

Equipment	1969	1973	1975-76
Recovery furnaces			
No. 1	280	Standby	NA[a]
No. 2	700	Standby	NA
No. 3	NA	ND	ND
Digesters	652	652	652
Multiple-effect evaporators	45	45	45
Smelt tank	18	18	18
Lime kiln	ND[b]	ND	ND
Total	1,695	DI[c]	DI

[a] NA - Not applicable.

[b] ND - No data.

[c] DI - Data incomplete.

responsible for about 60 percent of the reduced-sulfur emissions.

Much of the remaining 40 percent comes from the digesters and multiple-effect evaporators. Westvaco has not yet made a firm commitment regarding the method they will use to control these sources. Since the necessary control technology is available and has been applied at many pulp mills, the company's lack of a firm plan must be considered a major deficiency. Generally, these digester and evaporator emissions are controlled by venting the gases to a recovery furnace or lime kiln for incineration. According to the compliance plan, a decision concerning the digesters and multiple-effect evaporators will be made in July 1972, and the completion dates will be negotiated at that time.

Also, no mention has been made in the compliance schedule of eliminating the emissions from the knotter and brown stock washer. Finally, the condensate from the digester relief valves and the multiple-effects evaporator should not be used or discharged untreated into sewers or waterways. Condensate treatment must be considered and must become an integral part of any odor control program.

V. OTHER EMISSION SOURCES

The region is so sparsely settled that the contributions of automotive, home-heating, and other nonindustrial activities to the air pollution burden of the area are small relative to the pulp mill emissions. Only two other significant industrial emitters have been identified:

1. Cumberland Charcoal, Beryl, West Virginia. This small charcoal plant produces wood chips and charcoal briquettes. The plant includes a drier, a carbonizer, a scrubber, and an afterburner. Located directly across the river from Bloomington, the plant occasionally arouses complaints about its visible emissions.
2. Masteller Coal Company, Beryl, West Virginia. This company is engaged in coal preparation and cleaning and operates an air table to clean coal. The plant has been working with the West Virginia Air Pollution Control Commission to control its emissions. The plant uses a plant-made brattice-cloth-covered settling chamber/filter of unknown efficiency for the final control. There are normally no visible emissions. The West Virginia Air Pollution Control Commission has estimated that the plant complies with their Regulation V, and, on that basis, emits less than 11 pounds per hour (12 tons per year) under normal operation.

Although coal is still used as a fuel, more than half of the residential and commercial buildings in the area are heated with natural gas, a fuel which produces low emissions. Little fuel oil is burned in the area.

PRECEDING PAGE BLANK

VI. AIR QUALITY

Before air quality data are discussed, it must be noted that measurements made at a particular station are often not representative of the overall air quality. In the Luke-Keyser region, this fact is especially applicable because of the strong influence local topography has on measurements at any single measurement station. Frequently, significantly different results are obtained from stations less than 1 mile apart. The observations reported are thus indicative of the air quality, but do not quantify it.

SUSPENDED PARTICULATE

Suspended particulate levels in the study area exceed those recommended by EPA[1] (Part I, Section V). This is particularly true in Luke, where the concentration present, 140 $\mu g/m^3$ (1968 annual average), was almost twice the level proposed as a primary standard, 75 $\mu g/m^3$. Luke levels also compare unfavorably with the annual averages in New York City, 135 $\mu g/m^3$, and in Washington, D. C., 104 $\mu g/m^3$.[10]

Concentrations show a moderate seasonal trend, with winter levels 10 to 15 percent greater than the corresponding summer levels. This variation is particularly severe in Luke. Whether the Luke trend is the result of an abnormality in the data or of the effects of space-heating demands is not known. Possibly emissions from the pulp mill boilers are greater during the winter months because of the plant's space-heating requirements. The data are tabulated in Table 2-8.

Table 2-8. SUSPENDED PARTICULATES[a]
($\mu g/m^3$)

City	Winter	Spring	Summer	Fall	Annual average
Westernport	111	100	102	86	100
Luke	165	143	114	130	140
Bloomington	126	125	82	94	108
Keyser	-	-	-	-	94[b]

[a] Maryland data, 1968.[5]

[b] West Virginia data, February 1968 to November 1970.[5]

DUSTFALL

Dustfall levels in much of the study area are greater than the 15 tons per square mile per month generally considered acceptable in residential areas. In

PRECEDING PAGE BLANK

1968, the highest values occurred at the Bloomington School station, where the annual average was 30.9 tons per square mile per month, and the highest monthly average was the December value of 59.5 tons per square mile per month. Dustfall levels at Westernport, Maryland, were also high (Table 2-9).

Table 2-9. DUSTFALL, 1969[5]
(tons/mi^2-mo)

City	Winter	Spring	Summer	Fall	Annual average
Westernport	24.3	25.3	14.2	19.6	21.0
Piedmont	15.9	14.8	11.8	13.4	14.0
Bloomington School	32.4	33.1	19.6	38.1	30.9
Keyser	11.8	13.1	9.0	12.8	11.7

Like suspended particulates, dustfall concentrations show a moderate seasonal trend. The maxima usually occur during the colder months. The high values in the fall and winter are probably the result of less favorable dispersion conditions and heavy space-heating demands.

HYDROGEN SULFIDE

Hydrogen sulfide (H_2S) concentrations, measured by means of silver-tarnishing tests, indicated high H_2S levels in the cities near the pulp mill, and within the narrow Potomac River valley. More than 90 percent of the national samples taken during 1968 had values below the samples from Piedmont and Keyser (Table 2-10).[5]

Table 2-10. SILVER TARNISHING RATES, 1968[5]
(percentage reflectance loss/mo)

City	Winter	Spring	Summer	Fall	Annual average
Bloomington	78	82	79	92	82
Piedmont	94	78	89	95	89
Keyser	88	88	94	89	90

Hydrogen sulfide concentrations show no seasonal trend, further indicating that the main source of hydrogen sulfide is the pulp mill. Although mill emissions vary from day to day, they are relatively constant when averaged over a long period of time.

SULFUR DIOXIDE

Continuous Monitoring Equipment

One conductivity-type, continuous, sulfur dioxide monitor was operated in Westernport by the State of Maryland. Most of the levels recorded were low. The 1968 annual average concentration of 28 μg/m^3 (0.01 ppm) compares favorably with the primary standard of 80 μg/m^3 (annual arithmetic mean)[1] recently proposed by EPA. On at least one occasion, however, peak sulfur dioxide concentrations reached 1573 μg/m^3 (0.6 ppm) for 5 minutes. During the 5-day period in which this peak occurred, December 12, 1967, to December 17, 1967, the 24-hour average concentrations approximated the proposed EPA primary standard of 365 μg/m^3. The possibility exists that considerably higher concentrations existed at other locations in the Luke-Keyser area that are more prone to high pollutant levels because of the source location and local topography.

Sulfation Plates

Since 1967 sulfation plates have been used as static indicators of sulfur dioxide levels in the area. They has been maintained jointly by APCO and the two state agencies.

The data indicate wide variations in sulfur dioxide concentrations within any given area. As shown in Table 2-11, the 1968 fall averages at the two Piedmont stations varied by a factor of three; the winter and summer averages at the three Keyser stations varied by a factor of almost two. These variations illustrate the effects of the topography and meteorology of the area.

Table 2-11. AVERAGE SULFATION RATES, 1968[a]
(mg SO$_3$/100 cm^2-day)

City	Winter	Spring	Summer	Fall	Annual
Bloomington[b]	1.0	0.5	0.3	0.7	0.6
Bloomington[c]	1.1	0.5	0.3	0.6	0.6
Piedmont[b]	1.9	0.7	0.4	0.5	1.0
Piedmont[d]	1.3	0.6	1.4	1.5	1.2
Keyser[b]	1.5	0.7	0.7	1.0	1.0
Keyser[d]	1.2	0.7	1.3	0.8	1.1
Keyser[d]	0.8	0.5	0.7	0.8	0.7

[a] Rounded off where necessary.

[b] NAPCA, National Effects Network data.[5]

[c] Maryland Division of Air Quality data.[5]

[d] West Virginia Air Pollution Control Commission data.[11]

In 1970, a more extensive network of sulfation plates was installed as part of this technical investigation. Data from these monitors indicated that relatively high sulfur dioxide concentrations can occur in some sections of the study area (Table 2-12). Again, wide variations in data were found from one sampling station to another. Particularly high sulfation rates occurred at the stations located just opposite the pulp mill on the Piedmont ridge. The highest sulfation rate, 4.9 mg SO_3 per 100 cm^2 per day is roughly equivalent to an average sulfur dioxide concentration of 0.17 ppm for a period of 1 month[11] (conversion factor used: ppm = 0.035 mg SO_3 per 100 cm^2 per day.

Table 2-12. AVERAGE SULFATION RATES, 1970[a]
(mg SO_3/100 cm^2-day)

Station	Winter	Spring	Summer[b]	Fall	Annual
Keyser[c]	1.2	1.5	1.1	-	1.3
Keyser[c]	0.9	0.6	0.7	-	0.7
Keyser No. 478	-	-	0.5	-	-
McCoole No. 426	-	-	1.4	-	-
Piedmont[c]	1.4	1.2	1.6	-	1.5
Piedmont No. 423	-	-	4.0	-	-
Piedmont No. 425	-	-	1.2	-	-
Piedmont No. 466	-	-	0.7	-	-
Piedmont No. 479	-	-	2.4	-	-
Beryl No. 467	-	-	0.4	-	-
Beryl No. 427	-	-	0.5	-	-
Luke No. 476	-	-	0.2	-	-
Westernport No. 424	-	-	0.8	-	-

[a] All data rounded off where necessary.

[b] All summer dates given for APCO stations include September.

[c] Data supplied by West Virginia Air Pollution Control Commission.[11]

Overall, the 1970 sulfation data indicate that sulfur oxides are transported from Luke over the ridge at Piedmont and down the river valley toward Keyser. Along this path, areas protected by intervening ridges and prevailing valley winds experience considerably lower pollutant levels (Figure 2-5).

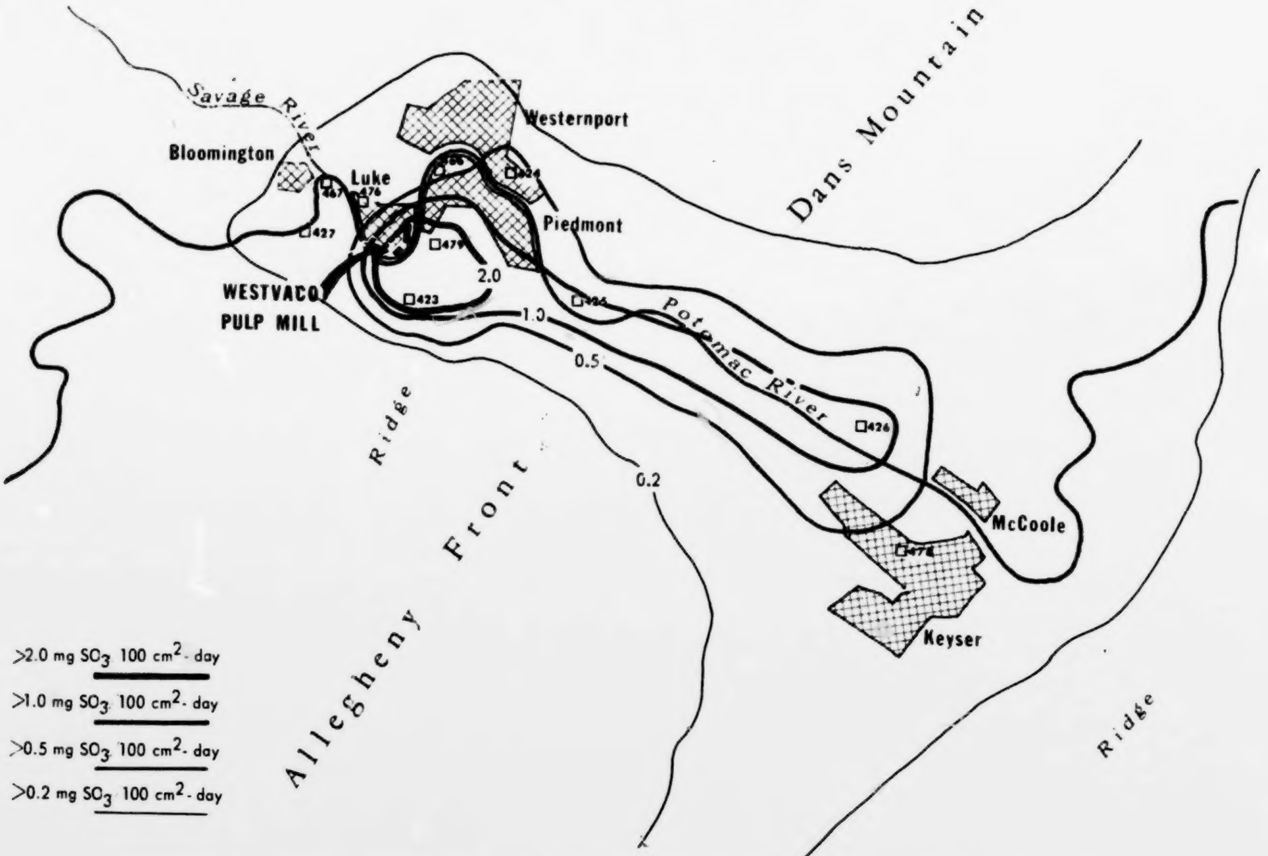

Savage River
Bloomington
Luke
Westernport
Piedmont
WESTVACO PULP MILL
Dans Mountain
Potomac River
Ridge
Allegheny Front
McCoole
Keyser
Ridge
427
423
479
426
2.0
1.0
0.5
0.2
>2.0 mg SO3 100 cm2- day
>1.0 mg SO3 100 cm2- day
>0.5 mg SO3 100 cm2- day
>0.2 mg SO3 100 cm2- day

Figure 2-5. Spatial distribution of sulfur dioxide as indicated by sulfation plate data.

VII. EFFECTS

The major air pollutants in the Luke-Keyser area are particulate matter, sulfur oxides, and reduced-sulfur compounds. The effects of these will be discussed in terms of: (1) visibility reduction, (2) material damage, (3) vegetation damage, and (4) effects on man.

VISIBILITY REDUCTION

The effects of emissions on visibility are illustrated by a photograph of the Luke-Westernport-Piedmont area (Figure 2-1). Atmospheric conditions at the time of the photograph prevented proper dispersion of the pollutant and water vapor emissions, concentrating them, instead, in one of the main residential areas in the region. The clear conditions existing north of Westernport are in striking contrast to the conditions in the river valley. The frequency of such occurrences may be greater in the summer (the time of the photograph) because of the decreased number of low-pressure storm systems traversing the area during this season.

MATERIAL DAMAGE

Effects of pollutants on materials have been observed by exposing selected materials to the atmosphere. This sampling program has been carried out as part of a national attempt to determine relative effect-levels. A silver-tarnishing test is used to evaluate levels of hydrogen sulfide. When exposed to air containing hydrogen sulfide, the silver develops a visible silver sulfide tarnish that differs from the normal silver oxide tarnish that forms with time when silver is exposed to air. The tarnishing rate is then determined by the decrease in reflectance after exposure. This test has proved reliable as a qualitative measurement of hydrogen sulfide levels.

Steel corrosion-rate tests provide an indicator of damage caused by the sulfur oxides. When sample steel plates are placed in an atmosphere containing sulfur oxides and moisture, they corrode and lose weight in proportion to the degree of corrosion.

Color changes in a specially prepared fabric dye reflect overall air quality because the dye is sensitive to a variety of pollutants, and loses color when it reacts with the contaminants.

Table 2-13 summarizes the material damage data in terms of national percentile rank. The numbers indicate the percentage of the 200 stations in APCO'S

PRECEDING PAGE BLANK

National Effects Network that had a smaller effect than the station for which the number is given. (The data are for 1968.)

Table 2-13. EFFECTS COMPARISON, 1968
(national percentile rank)

Test	Bloomington	Piedmont	Keyser
Steel corrosion rate	85	82	72
Fabric color change	49	45	39
Silver tarnishing	83	90	100

As the data indicate, material degradation due to hydrogen sulfide and sulfur oxides is markedly higher in the Luke-Keyser area than in other areas monitored by the National Effects Network. The majority of the stations in that network are in metropolitan areas.

VEGETATION DAMAGE

This study included no quantitative vegetation surveys. A field trip report[12] graphically describes the obvious vegetation damage that occurs in the immediate vicinity of the Luke pulp mill as a result of its emissions: "The conifer damage is most severe on the mountain directly east of the Kraft pulp mill and, in fact, a swath devoid of trees delineates the path of the mill's toxic emissions over the past years."

EFFECTS ON MAN

No studies have been made to determine physiological effects from air pollution in the Luke-Keyser area. Studies conducted in other metropolitan areas indicate, however, that air pollution of the magnitude found in the study area contributes to chronic bronchitis and respiratory damage.

The psychological effects of an odor are highly subjective. Thus the nuisance value of an odor depends on the attitude of the person, his disposition, and the time of day. The influence of odors on the health and comfort of man is difficult to prove. They may cause, however, both mental and physiological effects such as nausea, headache, loss of sleep, and loss of appetite.

Perhaps more important, offensive odors can ruin community and personal pride, discourage capital improvements, and damage a community's reputation. Economically, they can stifle growth and development of a community. In addition, tourists tend to shun such areas.

VIII. REFERENCES

1. National Primary and Secondary Ambient Air Quality Standards and Air Pollution and Control. Federal Register, Part Two, 36 (21): 1502. January 30, 1971.

2. The Nation's River. U. S. Department of Commerce. Washington, D. C. 1968.

3. 1960 Census. U. S. Department of Commerce. Washington, D. C.

4. 1970 Census. U. S. Department of Commerce. Washington, D. C.

5. Alkire, H. L. Air Pollution in Allegany County, Maryland. Division of Air Quality Control, State of Maryland. Annapolis, Maryland. July 1970.

6. Abatement Procedures Presently in Use or Feasible. In: E. R. Hendrickson, ed., Proceedings of the International Conference on Atmospheric Emissions from Sulfate Pulping. University of Florida, Deland, Florida. April 1966.

7. Private communication from George P. Ferreri and Felipe Lebron, Division of Air Quality Control, State of Maryland, Annapolis, Maryland. To: U. S. Environmental Protection Agency, Air Pollution Control Office, Durham, North Carolina. March 3, 1971.

8. Private communication from Steve Smallwood, West Virginia Air Pollution Commission, Charleston, West Virginia. To: U. S. Environmental Protection Agency, Air Pollution Control Office, Durham, North Carolina. February 22, 1971.

9. State of Maryland. Regulations Governing the Control of Air Pollution in Area I, 43P02. January 28, 1969. Baltimore, Md. Maryland State Department of Health. 10 p.

10. Air Quality Criteria for Particulate Matter. U. S. DHEW, PHS, National Air Pollution Control Administration. Publication No. AP-49. Washington, D. C. March 1970.

11. Private communication from Philip C. Zinn, West Virginia Air Pollution Control Commission, Charleston, West Virginia. To: U. S. Environmental Protection Agency, Air Pollution Control Office, Durham, North Carolina. December 21, 1970

12. Gordon, C. C. Damage to Christmas Trees Near Oakland, Maryland - Mt. Storm, West Virginia. Report to U. S. Environmental Protection Agency, Air Pollution Control Office, Durham, North Carolina. November 1969.

APPENDIX.

WESTVACO COMPLIANCE PLAN

PRECEDING PAGE BLANK

(Westvaco Letterhead)

June 25, 1970

Mr. George Ferreri, Head
Compliance Section
Division of Air Quality Control
Maryland Department of Health
2305 North Charles Street
Baltimore, Maryland 21218

Dear Mr. Ferreri:

The Luke, Maryland, mill of Westvaco Corporation is pleased to submit herewith its Plan for Compliance with Maryland's Air Quality Regulations.

In addition to setting forth our plans to control other emission sources, it also includes our program for Nos. 22 and 23 boilers which will have zero emissions of particulate matter and sulfur dioxide when they are out of service. Further details of this portion of our plan are discussed in my letter to you of January 16, 1970.

You also may wish to refer to the letter to you from O. B. Burns, our Water and Air Conservation Administrator, dated March 11, 1970, which expresses our confidence in the black liquor recovery system, particularly with regard to Total Reduced Sulfur (TRS), that we intend to have in operation by August 1972.

This letter cites the excellent results being achieved in controlling Total Reduced Sulfur (TRS) emissions at our Charleston, S. C., operation with similar equipment. We believe that the new No. 3 recovery furnace at Luke will yield results comparable to those at Charleston which we feel reflect the best efforts in the industry.

The general contract for construction of No. 3 recovery furnace has been awarded and site preparation is expected to begin by the last of this month. This is an $8.5 million project and includes an electrostatic precipitator as well as excess capacity built in solely for air pollution control.

Our new 240,000 pound-per-hour packaged steam boiler (No. 26) is under construction and is scheduled to be in operation by October of this year. This boiler will be fired with one per cent sulfur fuel oil and is being built at a cost of about $1.5 million.

Our program also indicates our confidence in the Westvaco process for the removal of sulfur dioxide from stack gases. We are extremely pleased with the way this development has come along and we believe it will be a real benefit to the improvement of air quality not only in Maryland but across the country.

Very truly yours,
(signed)
Arthur L. Noble
Mill Manager

PLAN FOR COMPLIANCE WITH MARYLAND AIR QUALITY REGULATIONS
By The
LUKE, MARYLAND, MILL OF WESTVACO CORPORATION

1. The Luke mill of Westvaco, Luke, Maryland, 21562 (hereinafter referred to as the Company), hereby submits a Plan for Compliance to bring its operations within the requirements of Regulations Governing the Control of Air Pollution in Area 1, promulgated pursuant to Article 43, Section 697 of the Annotated Code of Maryland.

2. Solely for the purposes and terms of this Plan for Compliance, the Company hereby waives any obligations which the Maryland State Department of Health (hereinafter referred to as the Department) may have to forward a Notice of Violation which may be required under Article 43, Section 698 (a) as it pertains to any violation of the regulations set out in Paragraph (1) above, caused by the operation of the installations referred to in Paragraph 4, below.
The Company further waives those provisions of Article 43, Section 698 (b) and (c), and agrees that this Plan for Compliance as it relates to those installations referred to in Paragraph (4) may be enforced by the Department to the same extent as if the acts to be performed under the Plan by the Company were ordered by the Secretary of Health and Mental Hygiene after a hearing held pursuant to Section 698 (b) and (c) of Article 43.

3. The Company represents that in its usual and ordinary operations, it is unable to achieve the emission standards set out in the regulations referred to in Paragraph (1), above.

4. The Company represents that it will conduct its operations in such a manner that it will be in compliance with the regulations referred to in Paragraph (1) above, by proceeding in accordance with the following schedule:

   A. A new 240,000 pound-per-hour packaged steam boiler (No. 26) will be installed and placed in operation by October 1970. This boiler will be No. 6 oil-fired and will meet regulations 43P020202, 43P020301 (Figure 2), and 43P020402.

   B. A new black liquor recovery boiler (No. 3) will be installed by August 1972, and will be equipped with an electrostatic precipitator control system. This new black liquor burning equipment is of such design to significantly reduce the amount of total reduced sulfur (TRS) compounds compared to the two (No. 1 and No. 2) existing recovery boilers. The new No. 3 recovery boiler will meet regulations 43P020204B and 43P020303. This stack will be monitored on a continuous basis with the objective of complying with 43P020401.

C. The existing No. 22 and No. 23 boilers will be placed on emergency standby in December 1970 after stable operation of No. 26 boiler is achieved. The No. 22 and No. 23 boilers will be retired from service in November 1972 after stable operation of No. 3 recovery boiler is achieved.

D. The existing No. 1 and No. 2 recovery boilers will be placed on emergency standby status in November 1972 after stable operation of No. 3 recovery boiler is achieved.

E. Compliance with regulation 43P020403 (Gaseous Sulfur Compounds from the Burning of Other Fuels) will be achieved under the following schedule:

Parallel investigations of two (2) alternate solutions with the provision that No. 24 and No. 25 boilers can be converted at any time to burn No. 6 oil with a sulfur content of 1% or less by weight in the case that Westvaco determines that neither of the two alternate solutions under investigation proves feasible. The two possible solutions are (1) the development and application of the Westvaco Activated Carbon Process for the desulfurization of flue gases; and (2) the utilization of local 1% (or less) sulfur coal reserves and the determination of the washability of other local coal reserves to obtain 1% (or less) sulfur content. The investigation of these two areas will proceed as follows:

a. Westvaco Activated Carbon Process

Laboratory work will be completed by the Westvaco Research Group by October 1970. Design, construction and operation of 4-inch pilot unit to be completed by July 1971. Design, construction and operation of 18-inch pilot unit to be completed by October 1972. Evaluation of pilot plant data will be completed by April 1973.

1. If the Westvaco Process is feasible:

Immediate installation of an electrostatic precipitator on No. 24 boiler to comply with regulations 43P020202 and 43P020301 (Figure 2). This precipitator would start up by August 1974. Design, engineer, and construct the

Westvaco Process to comply with regulation 43P020403. This Process would start up on No. 24 boiler by October 1975 and on No. 25 boiler by October 1976.

b. Utilization of Local Coal Reserves
    1. Continued detailed investigation through local coal suppliers to determine:
        a. The availability of low sulfur coal (1% or less) which can be used as mined, and
        b. The availability of higher sulfur coals that are amenable to washing to an acceptable sulfur content.

        This phase is to be completed by September 1971.
    2. If low sulfur coal is economically available:
        a. Rebuild the electrostatic precipitator on No. 25 boiler for use with low sulfur coal and compliance with regulations 43P020202, 43P020301 (Figure 2) and 43P020403. Begin work in April 1973 and complete rebuild by June 1974.
        b. Rebuild No. 24 boiler to burn low sulfur, high fusion coal and install electrostatic precipitator for compliance with regulations 43P020202, 43P020301 (Figure 2), and 43P020403. Complete rebuild and precipitator by February 1975.
    3. If low sulfur coal is not economically available but testing indicates economic availability of higher sulfur content coal which is amenable to washing to 1% (or less) sulfur content:
        a. Compare the economics of building and operating a Westvaco owned coal washery with the economics of buying washed coal from suppliers. This study will be concurrent with part 1 above.

c. If neither the Westvaco Process nor the utilization of local coal seams proves feasible, the Company will proceed with conversion of No. 24 and No. 25 boilers to burn #6 oil with a sulfur content of 1% or less by weight to comply with regulations 43P020202 and 43P020301 (Figure 2). No. 24 boiler will be converted to oil 18 months after decision. No. 25 boiler will be converted to oil 27 months after decision.

d. Part E of this Plan for Compliance shall be subject to annual review by the Department on the anniversary date of its approval. The program as described shall continue so long as it can be demonstrated to the satisfaction of the Department that adequate progress toward achieving compliance with the air pollution regulations in the manner set forth in this part of the Plan for Compliance is being made.

F. The discharge of odorous gases as quantified by total reduced sulfur compounds (TRS) will be substantially reduced by the installation of No. 3 Recovery Boiler. Emissions from the digesters and multiple effect evaporators are being studied. One promising approach is a new flame incinerating device to be installed and operated at another location. The Company is also researching other more sophisticated control methods which are at this time considered proprietary. On or before July 1972 the Company will report to the Department the results of these studies and choose a program for controlling these emissions. A completion date for such program will be negotiated at that time.

5. The Company will comply with all other existing regulations governing the control of air pollution in the State of Maryland and will not during the term of this Plan for Compliance exceed the emission levels resulting from its usual and ordinary operations.
6. The Company further represents that it will send detailed quarterly progress reports to the Department commencing three months from the date of approval of this Plan for Compliance.

(dated June 25, 1970)
Date

(signed)
Arthur L. Noble
Mill Manager

Recommendations

Approval of the foregoing Plan for Compliance is hereby recommended by the Division of Air Quality Control, Environmental Health Services.

(dated July 9, 1970)
Date

(signed)
Jean J. Schueneman, Chief
Division of Air Quality Control
Environmental Health Services

Approval of the foregoing Plan for Compliance is hereby recommended by Environmental Health Services.

(dated July 13, 1970)
Date

(signed)
Thomas D. McKewen, Director
Environmental Health Services
Dept. of Health and Mental Hygiene

Approval of Plan for Compliance

Upon agreements and representations made by the Company and upon the recommendations made by the above Departmental parties, the aforegoing Plan for Compliance is hereby approved this 14 day of July , 1970.

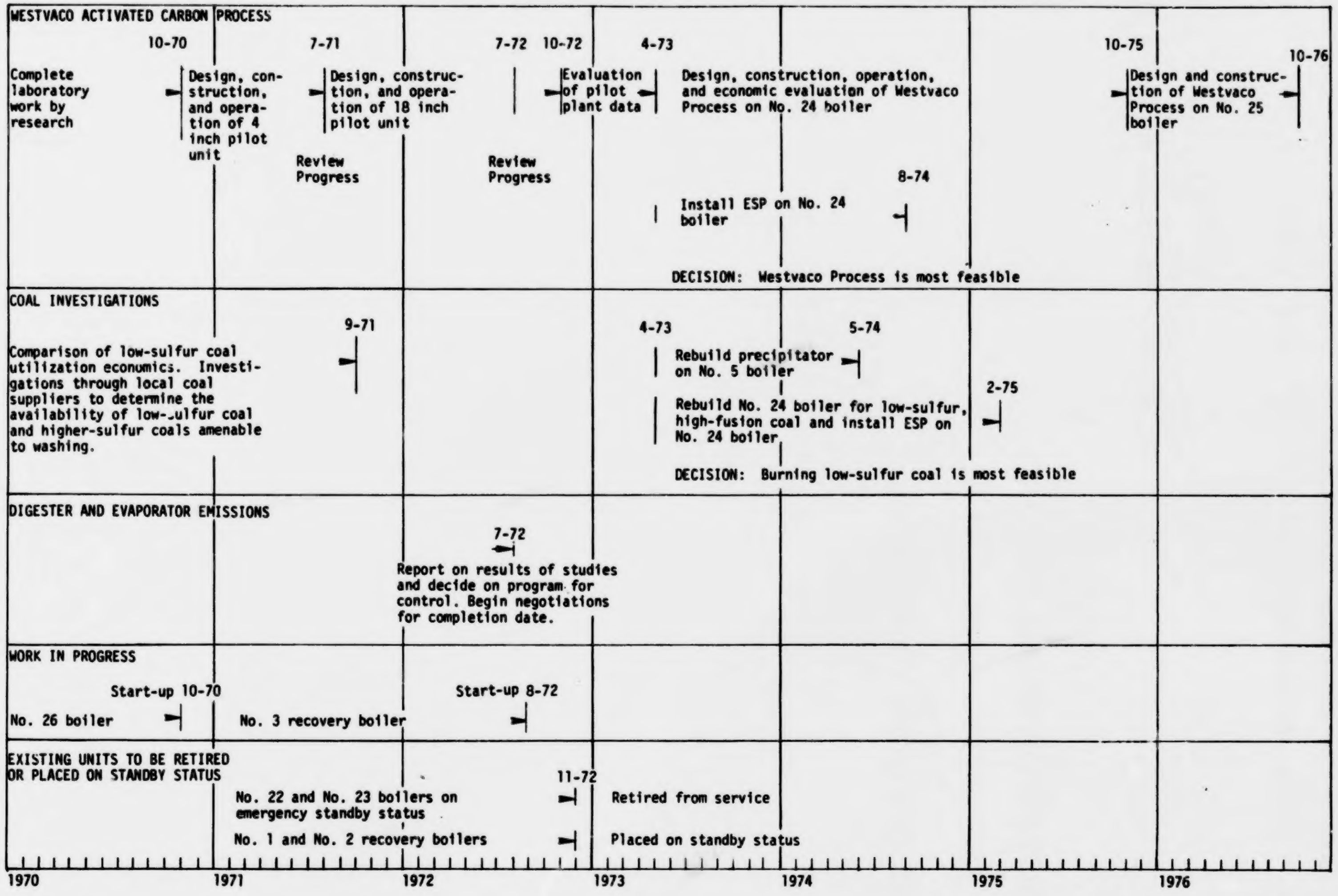
(signed)
Neil Solomon, M.D., Ph.D.
Secretary of Health and Mental Hygiene

APPROVED AS TO FORM AND LEGAL SUFFICIENCY

THIS 29th DAY OF June 19 70

(signed)
SPECIAL ASSISTANT ATTORNEY GENERAL

FLOW CHART FOR THE PLAN FOR COMPLIANCE AT THE LUKE MILL OF WESTVACO CORPORATION


WESTVACO ACTIVATED CARBON PROCESS
10-70
Complete laboratory work by research
Design, construction, and operation of 4 inch pilot unit
7-71
Design, construction, and operation of 18 inch pilot unit
Review Progress
7-72
10-72
Review Progress
Evaluation of pilot plant data
4-73
Design, construction, operation, and economic evaluation of Westvaco Process on No. 24 boiler
8-74
Install ESP on No. 24 boiler
DECISION: Westvaco Process is most feasible
10-75
Design and construction of Westvaco Process on No. 25 boiler
10-76
COAL INVESTIGATIONS
Comparison of low-sulfur coal utilization economics. Investigations through local coal suppliers to determine the availability of low-sulfur coal and higher-sulfur coals amenable to washing.
9-71
4-73
Rebuild precipitator on No. 5 boiler
5-74
Rebuild No. 24 boiler for low-sulfur, high-fusion coal and install ESP on No. 24 boiler
2-75
DECISION: Burning low-sulfur coal is most feasible
DIGESTER AND EVAPORATOR EMISSIONS
7-72
Report on results of studies and decide on program for control. Begin negotiations for completion date.
WORK IN PROGRESS
Start-up 10-70
No. 26 boiler
No. 3 recovery boiler
Start-up 8-72
EXISTING UNITS TO BE RETIRED OR PLACED ON STANDBY STATUS
No. 22 and No. 23 boilers on emergency standby status
11-72
Retired from service
No. 1 and No. 2 recovery boilers
Placed on standby status
1970
1971
1972
1973
1974
1975
1976